US 20060157235A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2006/0157235 A1

Allensworth

(43) Pub. Date: Jul. 20, 2006

(54) TERMINATION FOR SEGMENTED STEEL TUBE BUNDLE

(75) Inventor: **David Carter Allensworth**, Pearland, TX (US)

Correspondence Address:
ELIZABETH R. HALL
1722 MARYLAND STREET
HOUSTON, TX 77006 (US)

(73) Assignee: **OceanWorks International, Inc.**, Houston, TX

(21) Appl. No.: **11/244,465**

(22) Filed: **Oct. 6, 2005**

Related U.S. Application Data

(60) Provisional application No. 60/616,802, filed on Oct. 7, 2004.

Publication Classification

(51) **Int. Cl.**
E21B 19/00 (2006.01)

(52) **U.S. Cl.** **166/75.13**

(57) **ABSTRACT**

A termination and anchorage for steel helical segmented steel tubing bundles includes a set of multiple separable anchor blocks to which the individual tubes in the bundle can be attached and a clamp assembly for securing and supporting the set of anchor blocks. Multiple comating annular arcuate outer anchor blocks for the outer tubes in the tubing bundle surround a central anchor block, for the center tube in the tubing bundle. The aggregation of anchor blocks is compactly assembled and held together by surrounding the assembled blocks with a separable clamp assembly.

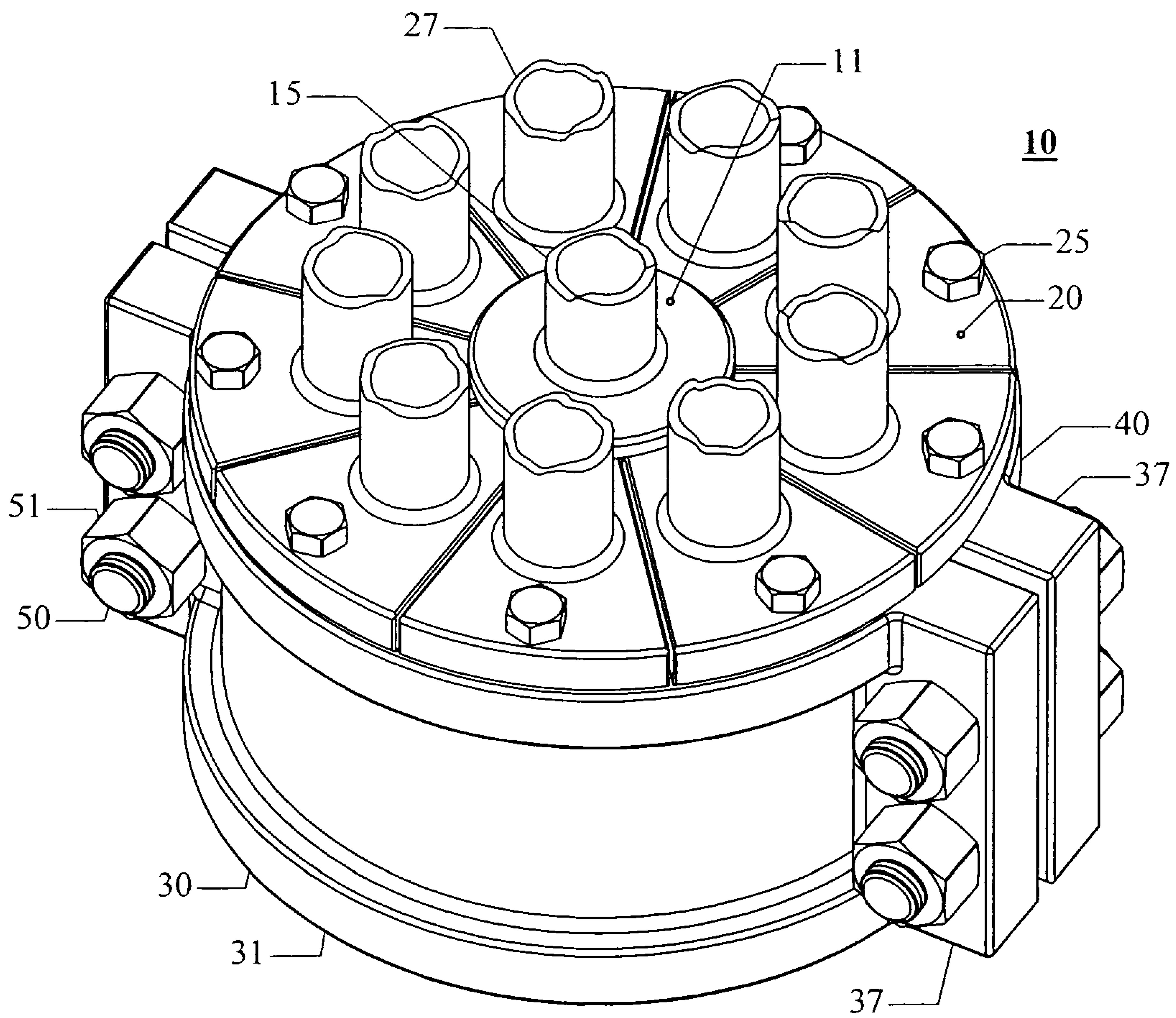


FIGURE 1

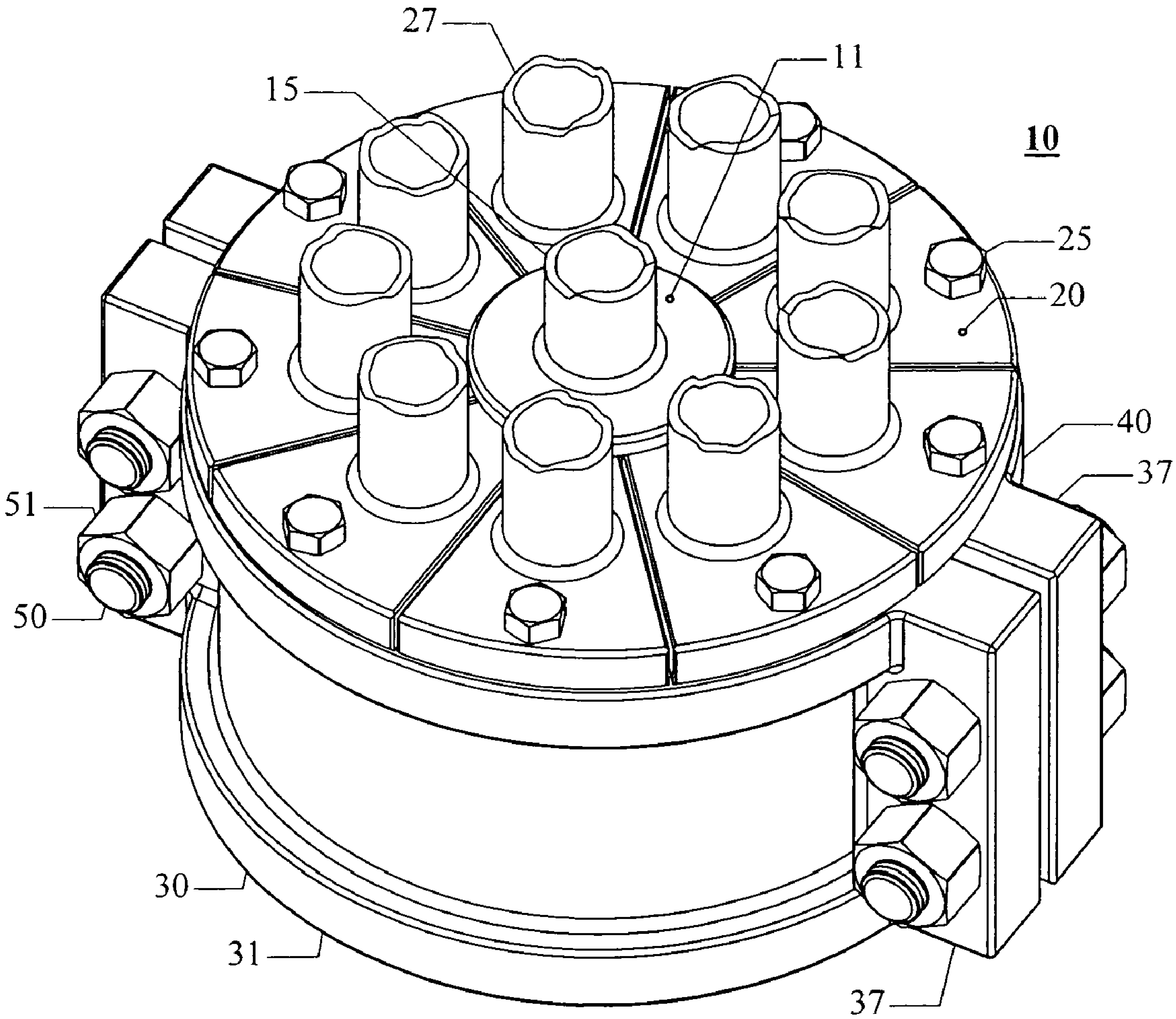


FIGURE 2

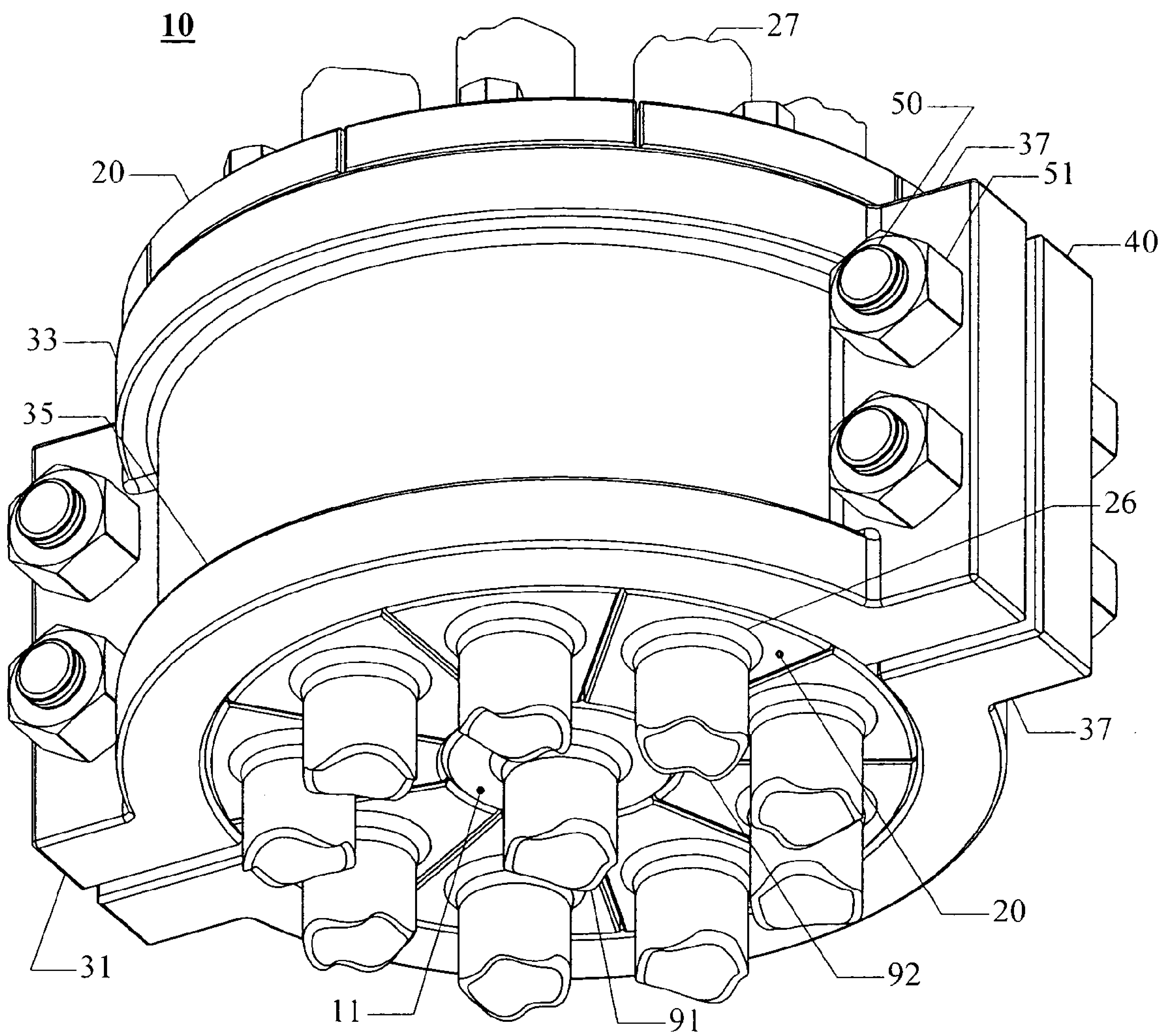


FIGURE 3

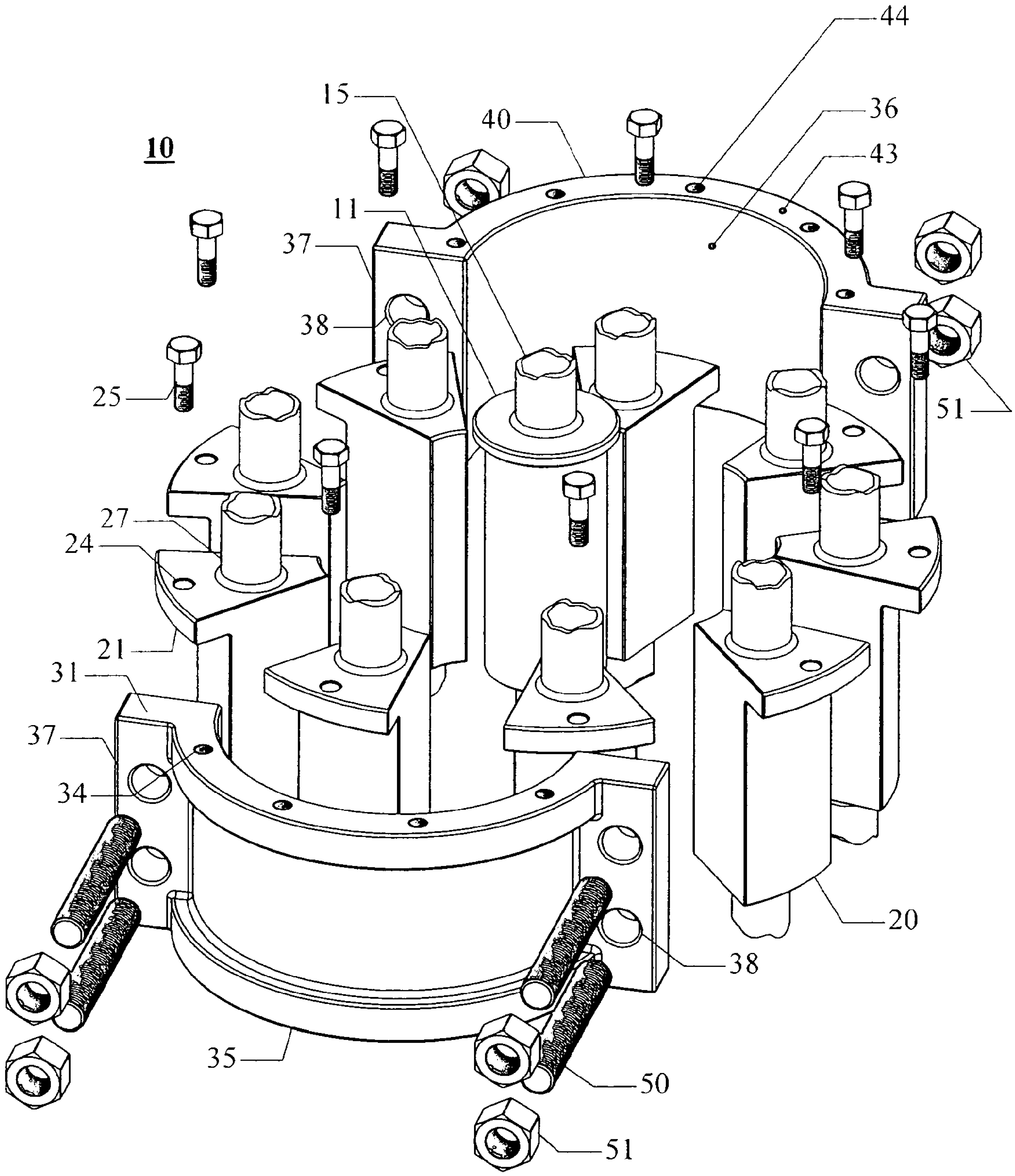


FIGURE 4

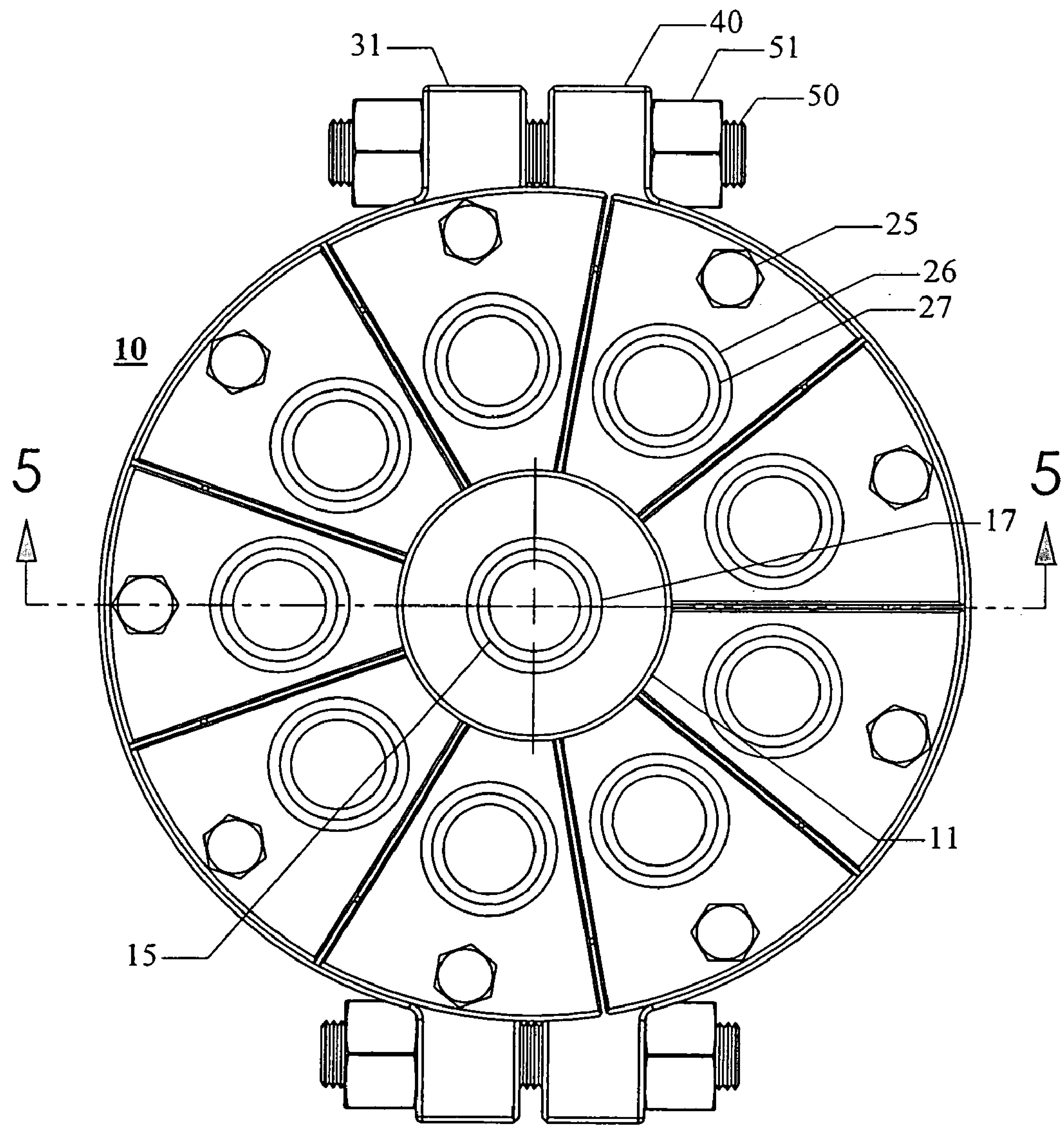


FIGURE 5

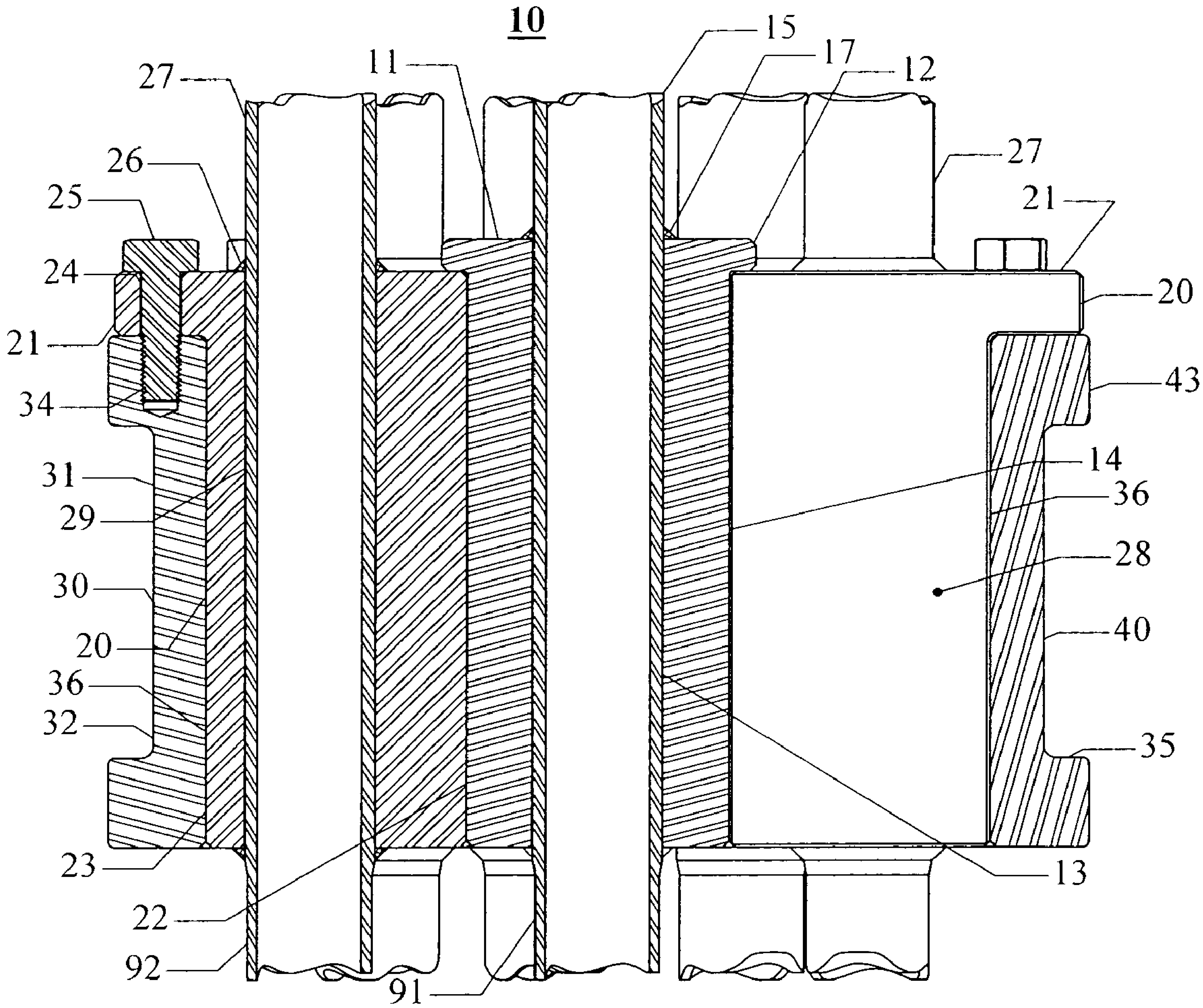

10
27
11
15
17
12
26
25
27
21
24
20
21
43
34
31
14
29
36
28
30
40
20
36
32
35
23
13
22
92
91

FIGURE 6

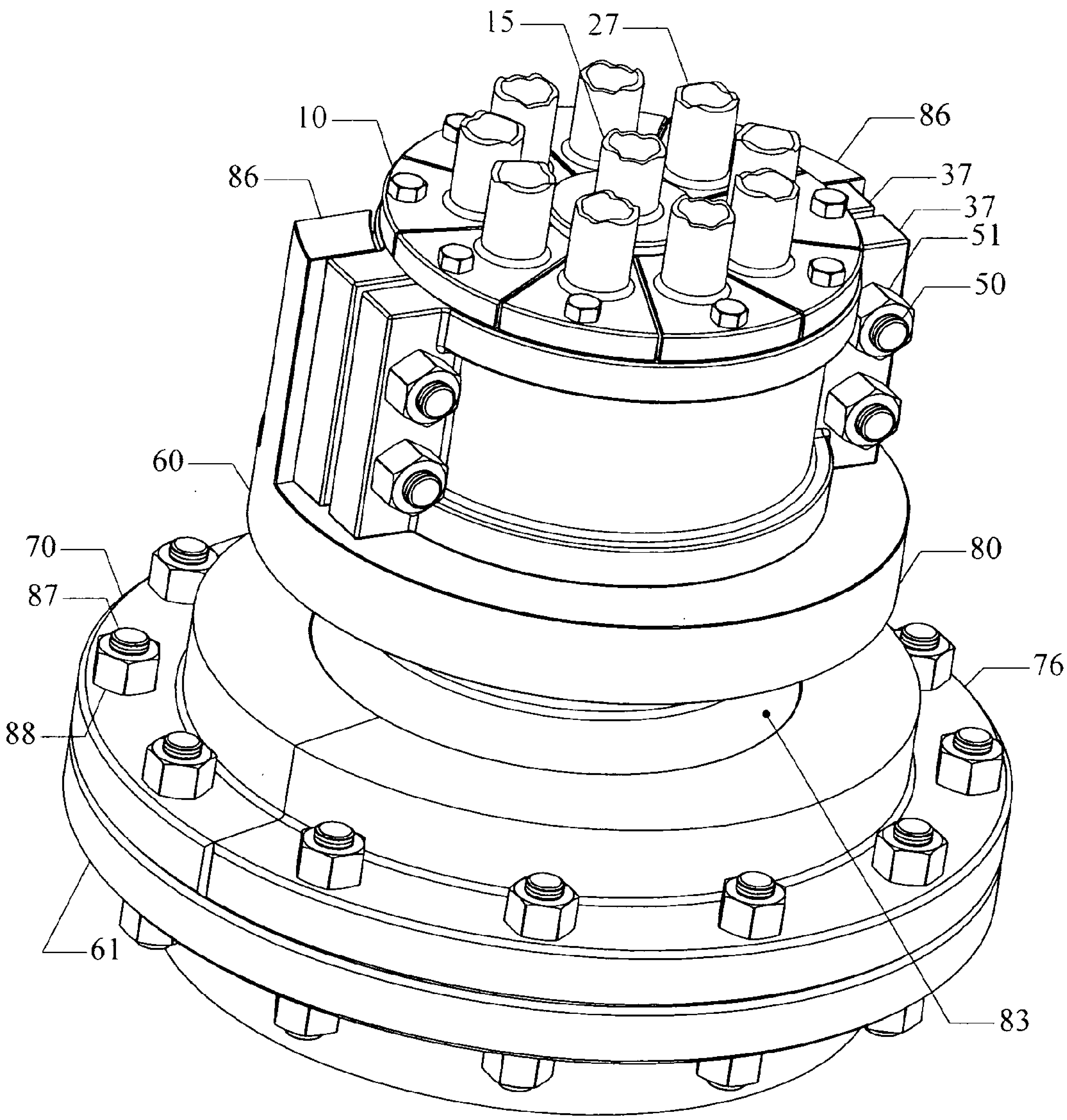


FIGURE 7

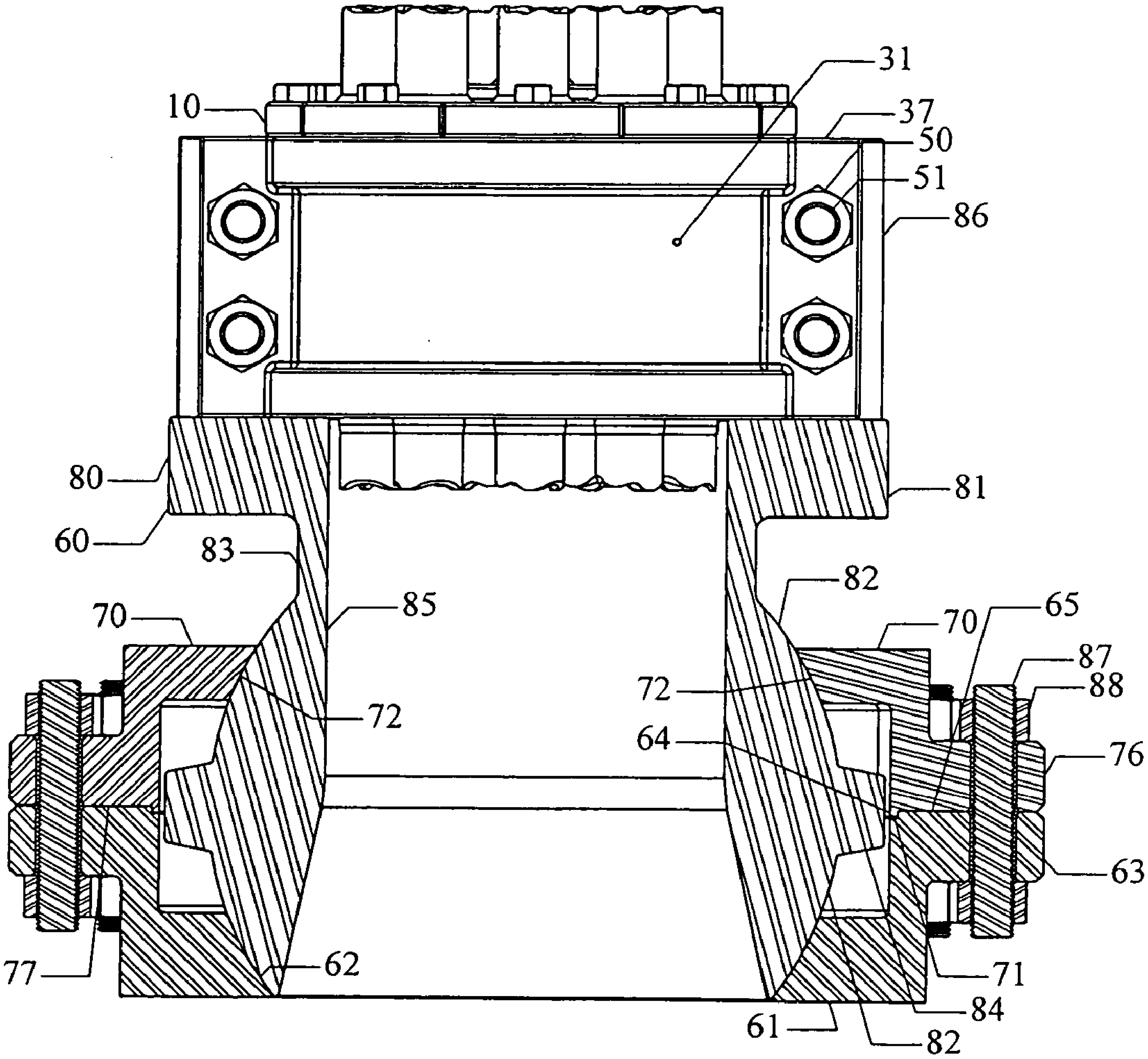

31
10
37
50
51
86
80
81
60
83
82
70
85
65
70
87
72
88
72
64
76
63
62
71
77
84
61
82

FIGURE 8

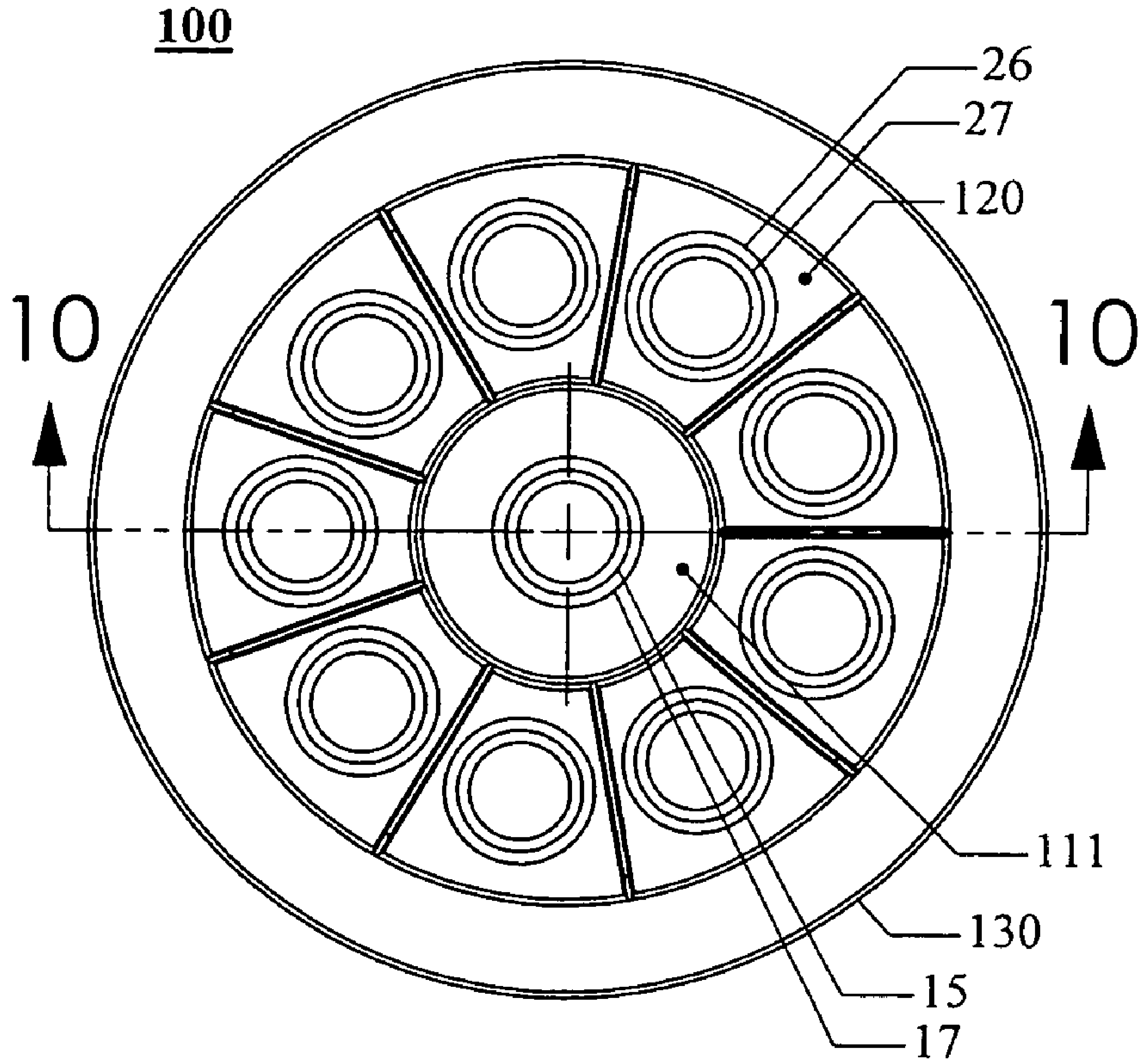


FIGURE 10

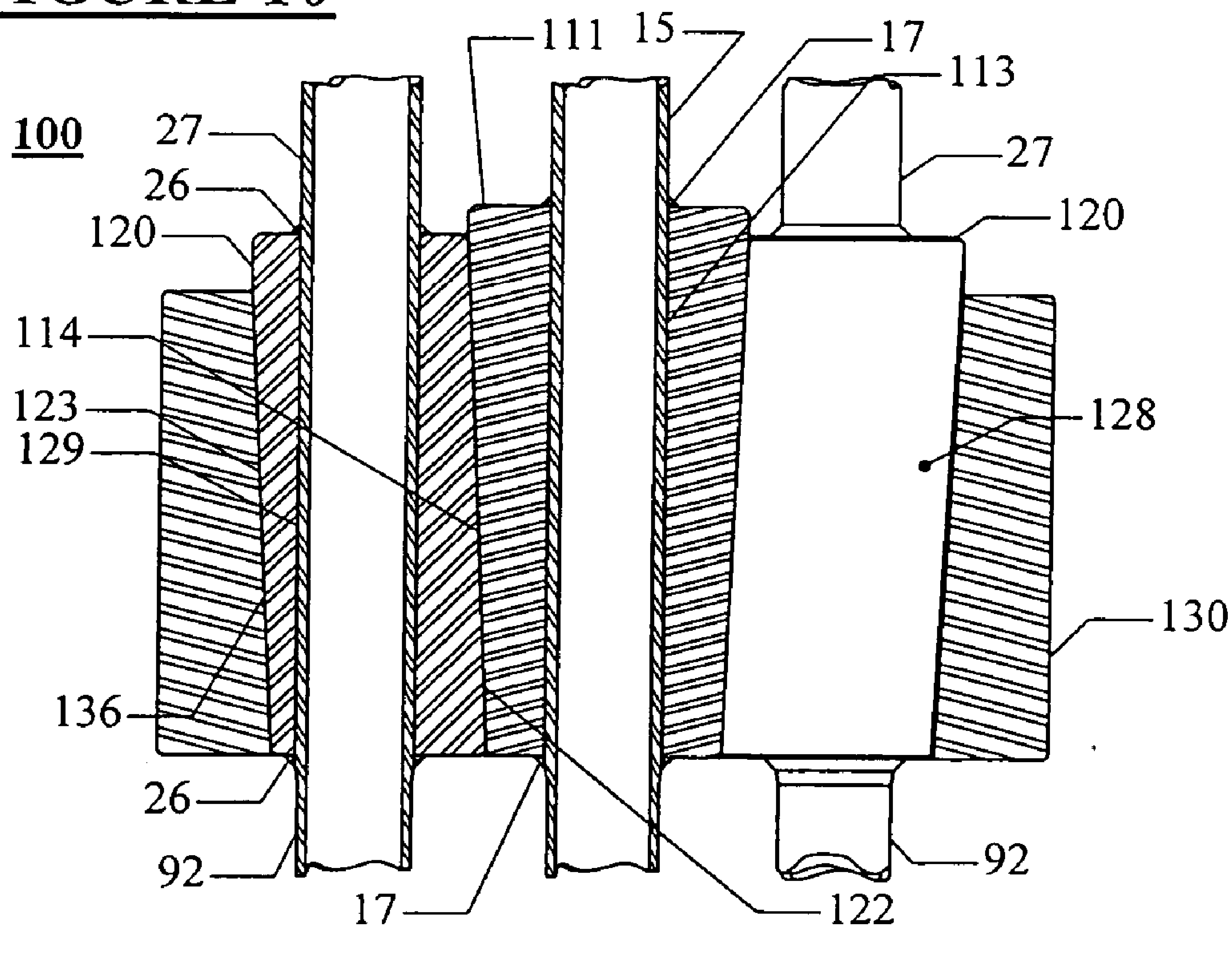
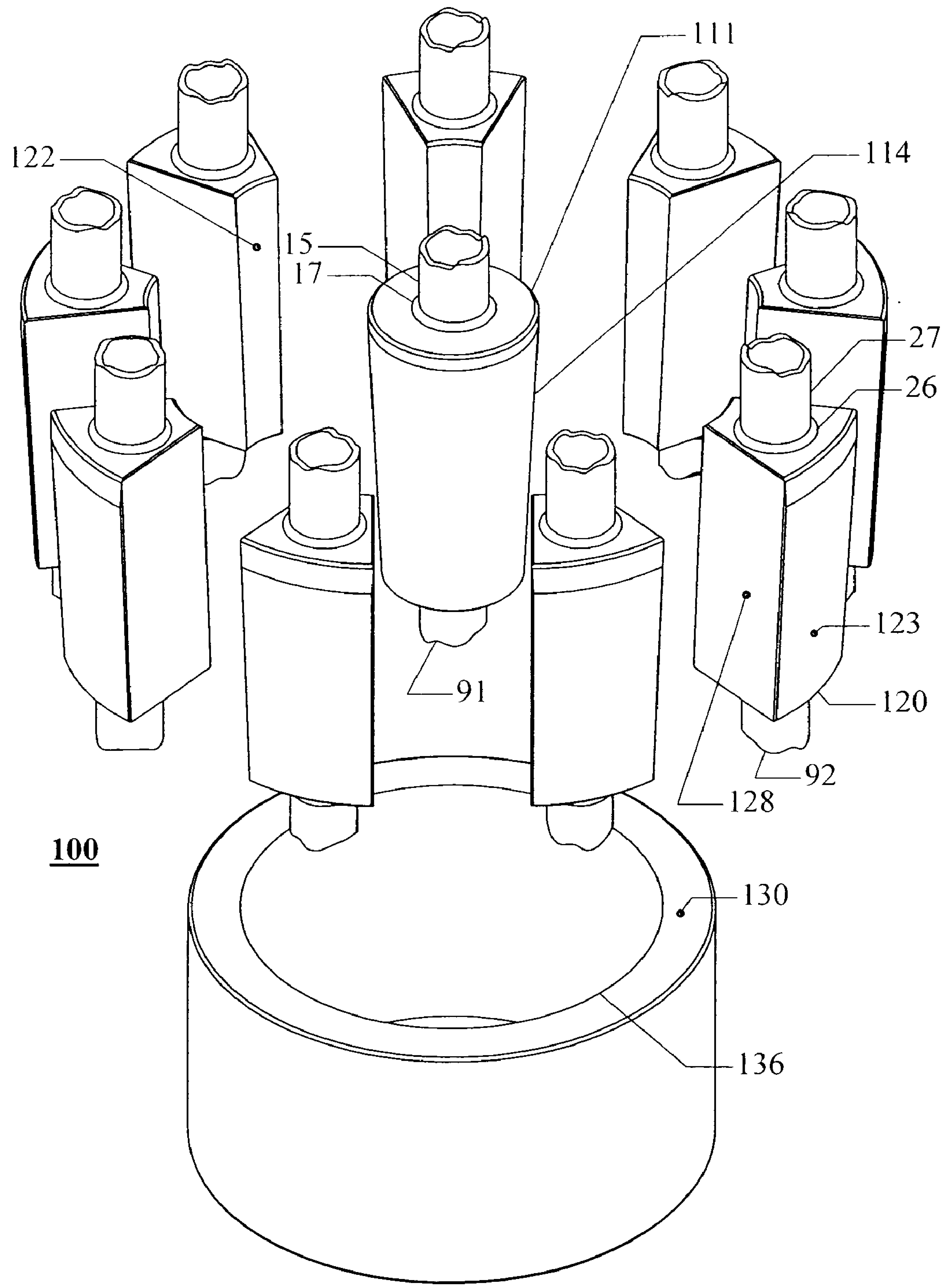


FIGURE 9



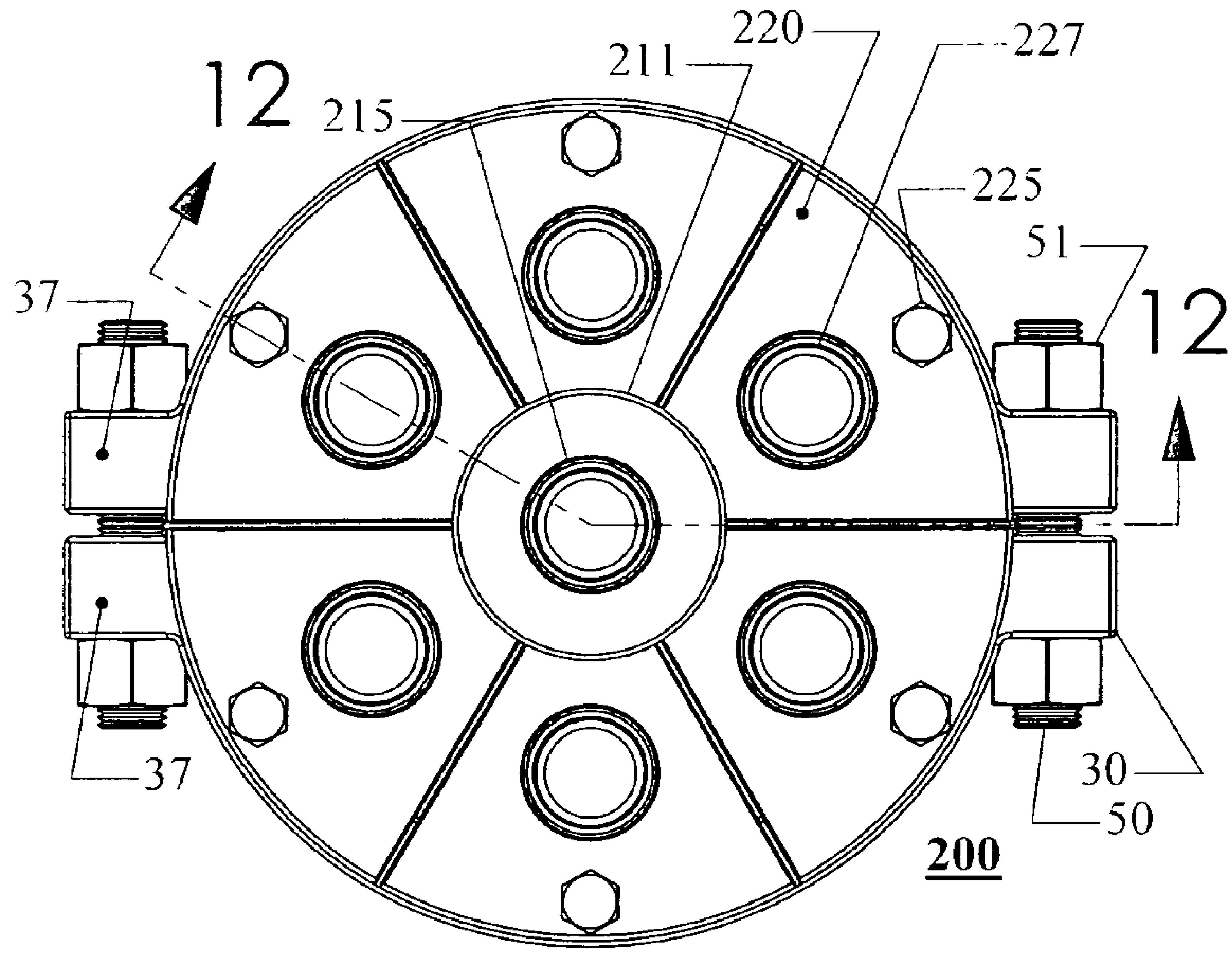


FIGURE 11

FIGURE 12

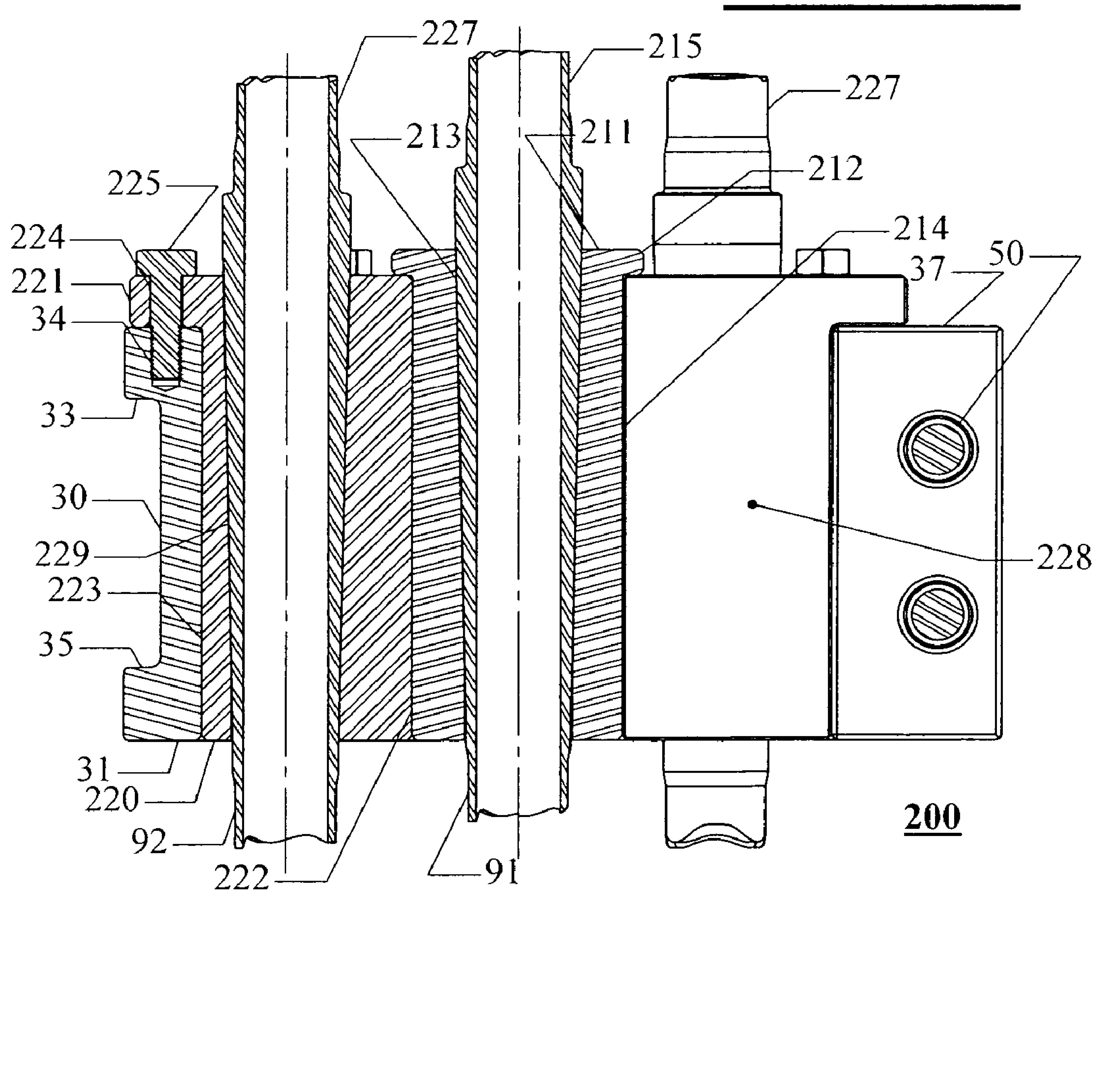


FIGURE 13

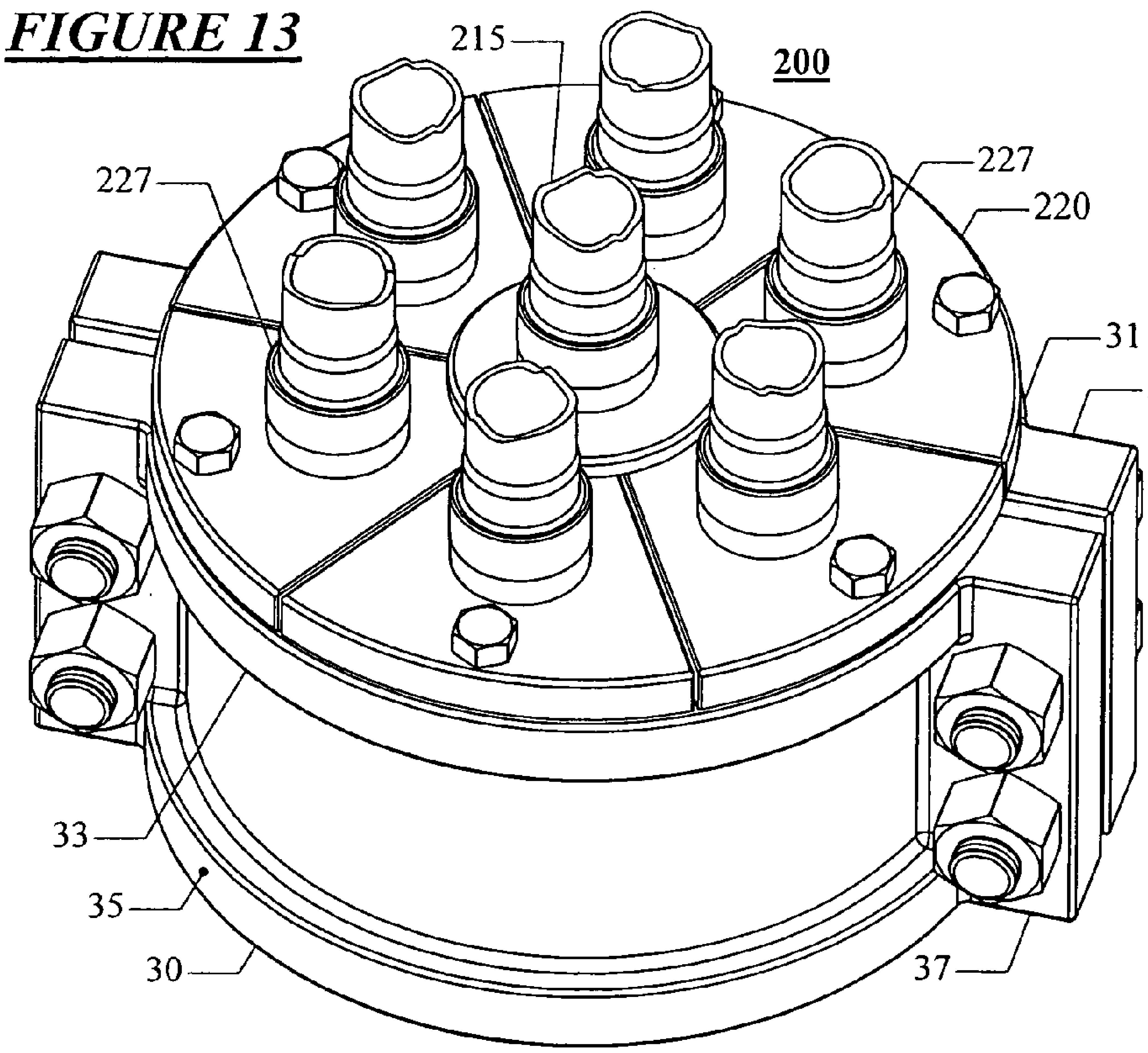


FIGURE 14

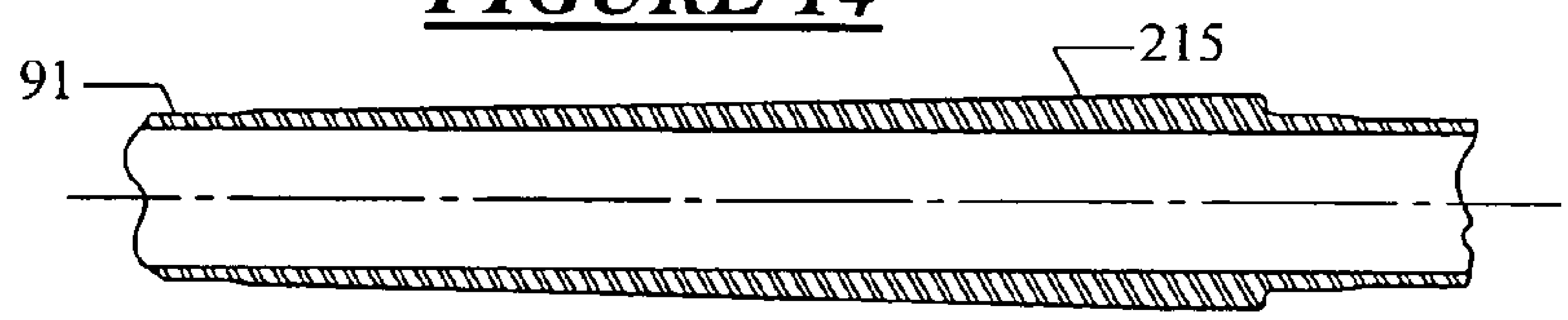


FIGURE 15

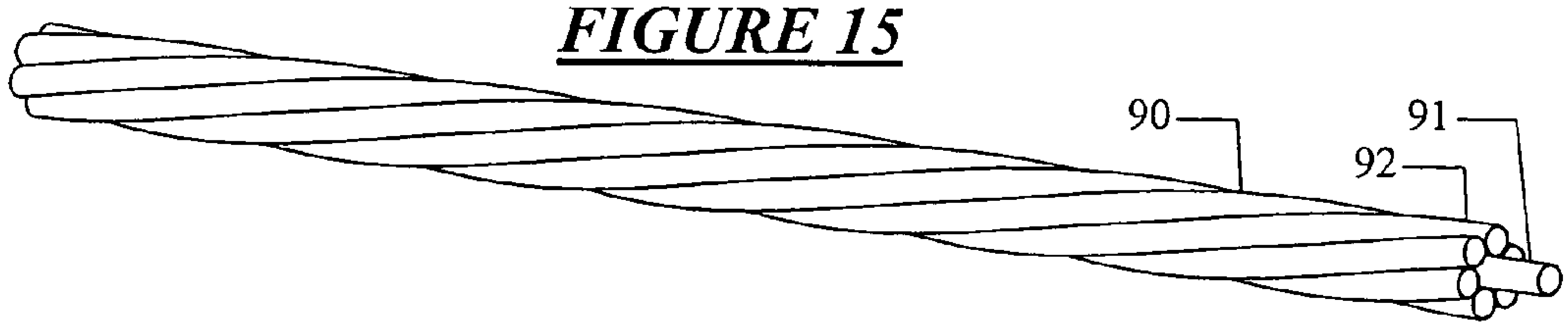


FIGURE 16

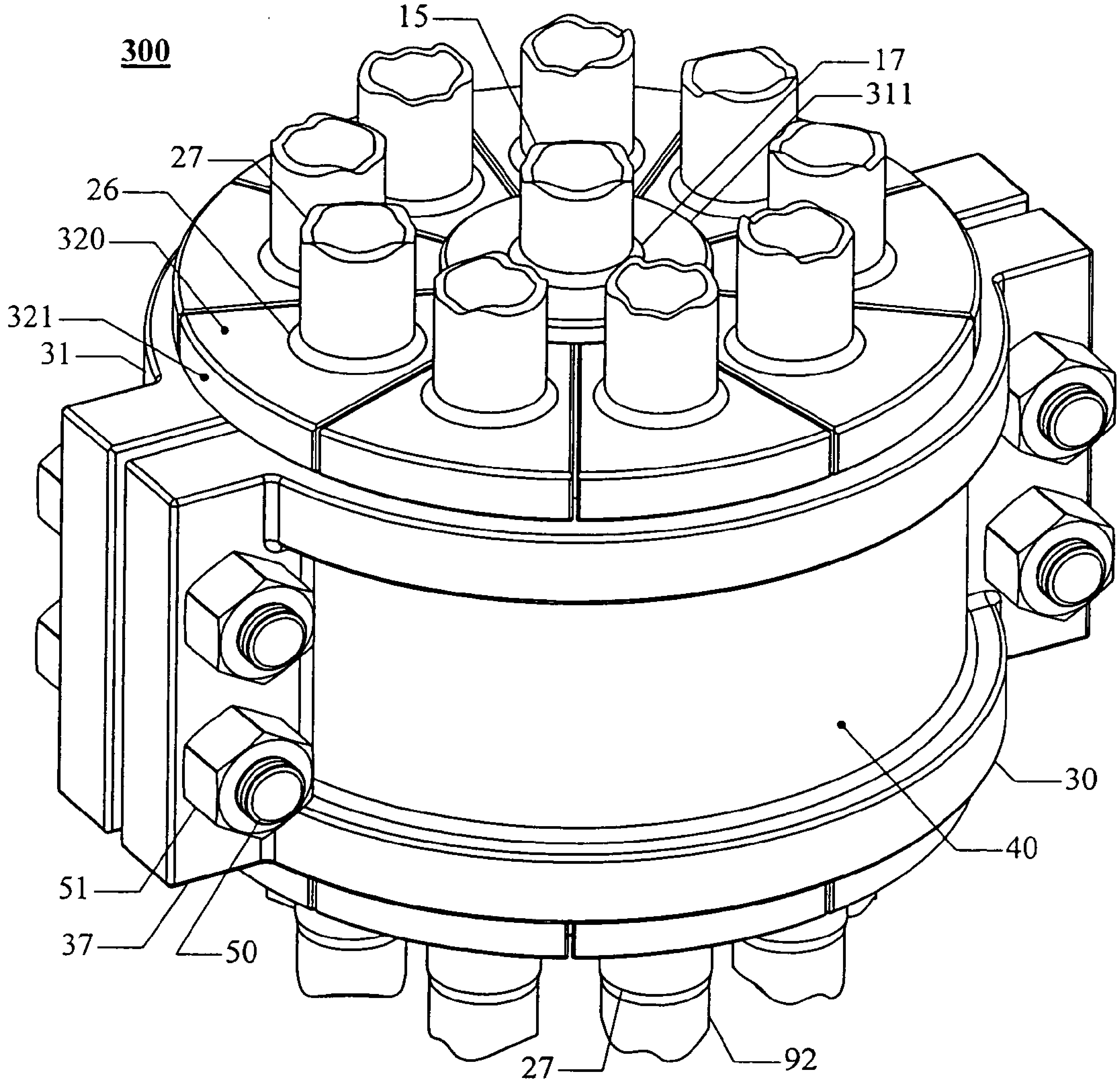
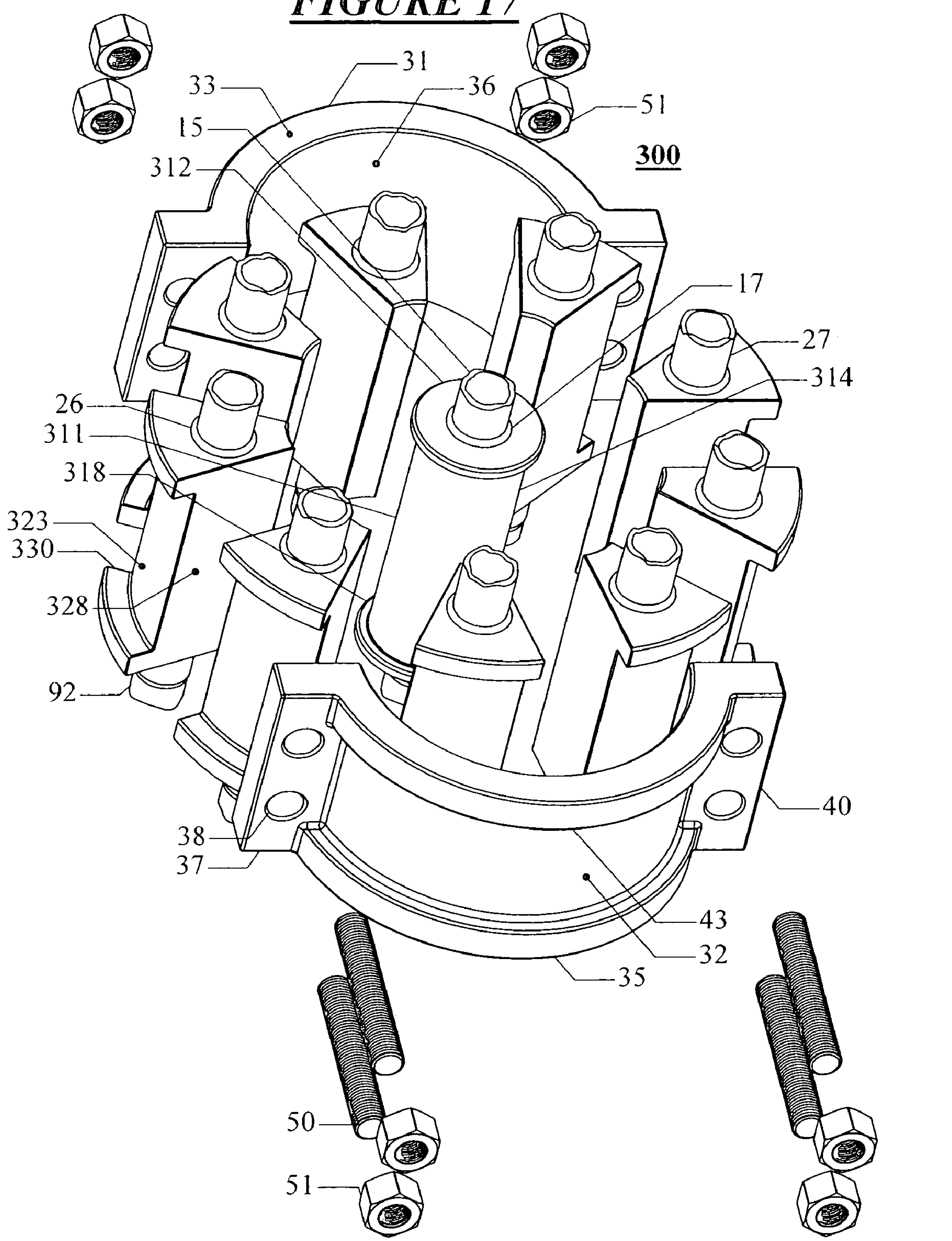


FIGURE 17


31
33
36
51
15
300
312
17
27
314
26
311
318
323
330
328
92
40
38
37
43
32
35
50
51

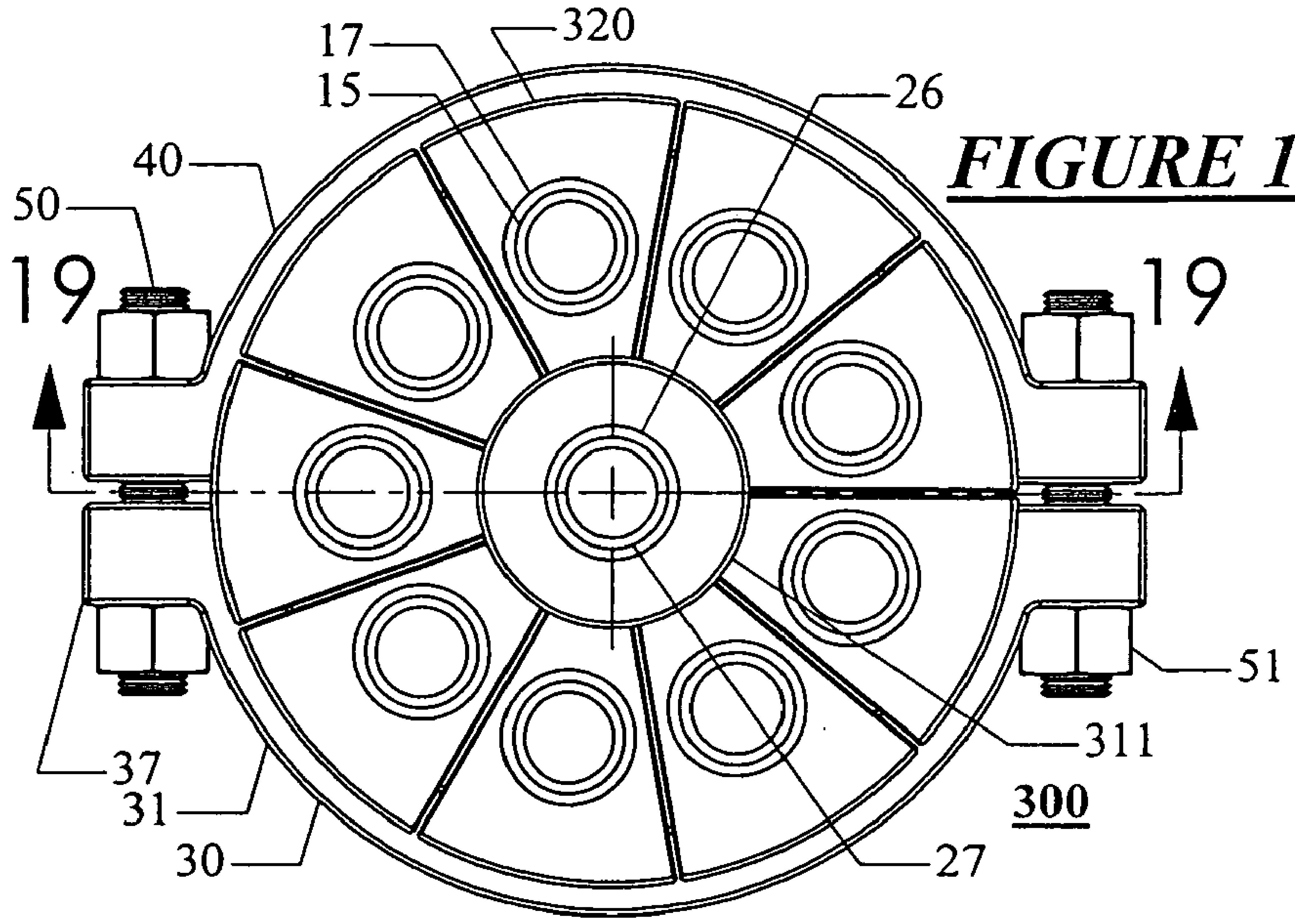


FIGURE 18

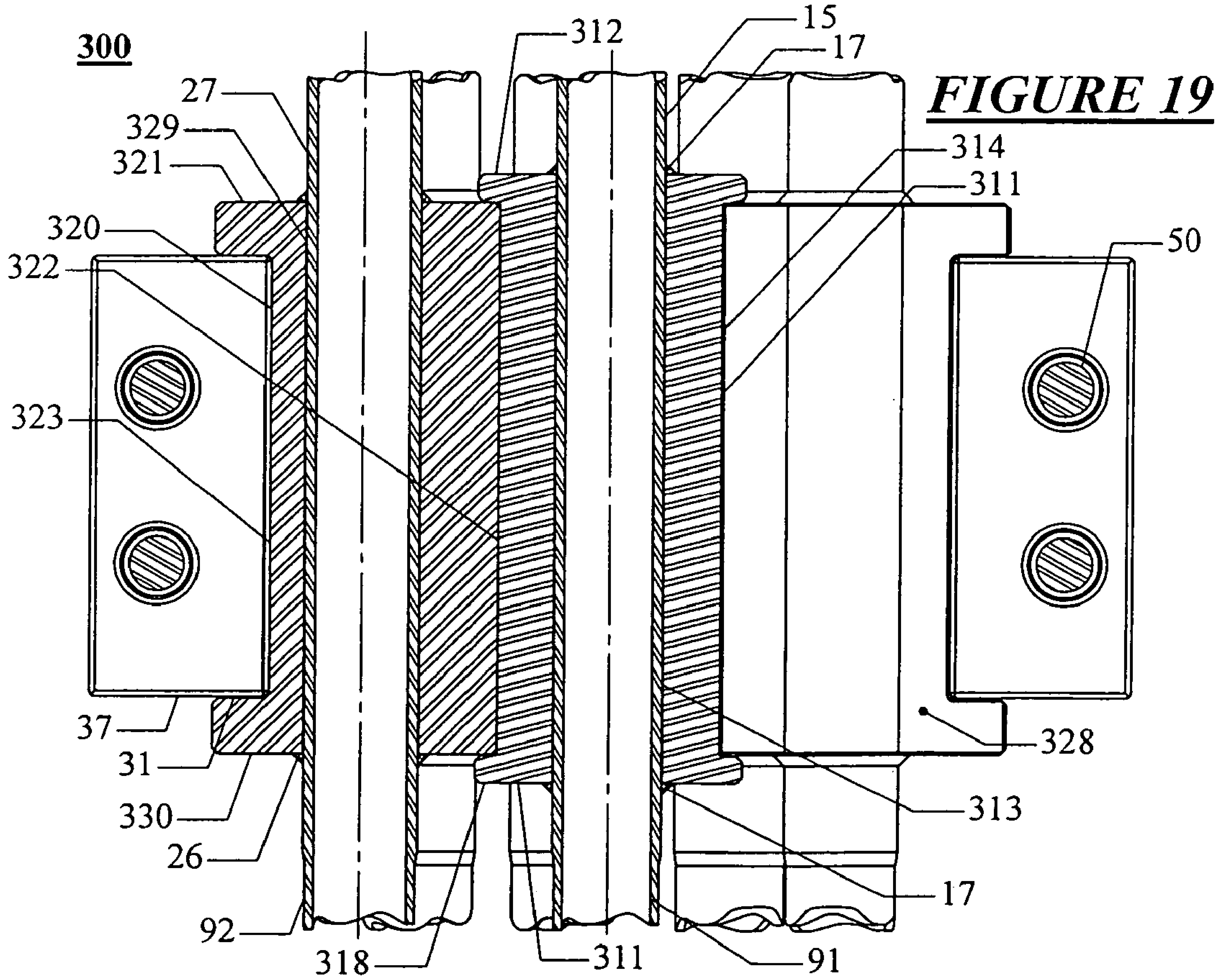


FIGURE 19

TERMINATION FOR SEGMENTED STEEL TUBE BUNDLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application, pursuant to 35 U.S.C. 111(b), claims the benefit of the filing date of provisional application Ser. No. 60/616,802 filed Oct. 7, 2004, and entitled "Segmented Steel Tube Bundle Termination."

BACKGROUND OF THE INVENTION

[0002] 1. Field Of The Invention

[0003] The present invention relates in general to a method and apparatus for connectors for subsea operations. More particularly, the invention relates to the termination and axial anchorage of helical steel control tubing bundles used for control lines for subsea wellheads in petroleum production.

[0004] 2. Description of the Related Art

[0005] Helical tubing bundles composed of a multiplicity of steel tubes are used routinely for hydraulic control functions and to convey other fluids to subsea wellheads used in petroleum production. The individual tubes are maintained in constant relative angular positions and are arrayed in a bundle in a helical pattern about a central core tube without torsion in the manner used to lay a torsionally balanced wire cable or fiber rope. These relatively flexible tube bundles in some cases can be subjected to high tensions, particularly during their subsea installation.

[0006] Current means for terminating the ends of the tube bundles are bulky and heavy. Typically, the individual tubes at the end of a bundle are displaced somewhat from the bundle longitudinal axis in order to permit connections to anchorages and other fittings to be made. These currently used end terminations are difficult to assemble, particularly if the tubes are welded into an anchor fitting, since sufficient space between tubes must be provided for the welder to operate. Potted anchorages likewise tend to heavy and bulky.

[0007] There exists a need for an apparatus and method that permits an easily assembled anchorage for subsea tube bundles having high tensile capacity.

SUMMARY OF THE INVENTION

[0008] The present invention relates in general to a method and apparatus for connectors for subsea operations. More particularly, the invention relates to the termination and axial anchorage of helical steel control tubing bundles used for control lines for subsea wellheads in petroleum production.

[0009] The present invention provides a novel type of termination and anchorage for steel helical control tubing bundles. The present invention includes a set of multiple separable anchor blocks to which the individual tubes in the bundle can be attached and a clamp assembly for securing and supporting the set of anchor blocks.

[0010] One aspect of the present invention has a central anchor block, for the center tube in the tubing bundle, surrounded by multiple comating annular arcuate outer anchor blocks for the outer tubes in the tubing bundle. The aggregation of anchor blocks is compactly assembled and held together by surrounding the assembled blocks with a separable clamp assembly. The separability of the anchor blocks permits maximum access to the attachment points of the tubing to the anchors, while at the same time allowing the tubings to be supported on minimal center-to-center spacings.

[0011] Another aspect of the present invention is

[0012] The foregoing has outlined rather broadly several aspects of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed might be readily utilized as a basis for modifying or redesigning the structures for carrying out the same purposes as the invention. It should be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0014] **FIG. 1** is an oblique view of the inlet/outlet end of a first embodiment of a tubing termination providing an anchorage for ten steel tubes.

[0015] **FIG. 2** shows the tubing termination of **FIG. 1** from its second side where the tubing bundle is attached.

[0016] **FIG. 3** is an oblique exploded view of the tubing termination of **FIGS. 1 and 2**.

[0017] **FIG. 4** is an axial plan view of the tubing termination of **FIGS. 1, 2**, and **3**, taken from the first side.

[0018] **FIG. 5** is a longitudinal sectional view of the tubing termination of FIGS. **1** to **4**, wherein the section is taken along line **5-5** in **FIG. 4**.

[0019] **FIG. 6** shows an oblique view of the tubing termination of **FIG. 1** mounted on a bend limiter device.

[0020] **FIG. 7** is a longitudinal section through the axis of the tubing termination and bend limiter of **FIG. 6**.

[0021] **FIG. 8** is an axial view from the first side of a second embodiment of the tubing termination of the present invention.

[0022] **FIG. 9** shows an oblique exploded view of the tubing termination of **FIG. 8**.

[0023] **FIG. 10** is a longitudinal sectional view of the tubing termination of **FIGS. 8 and 9**, taken along the line **10-10** in **FIG. 8**.

[0024] **FIG. 11** is a plan view of a third embodiment of the tubing bundle termination of the present invention.

[0025] **FIG. 12** is a vertical sectional view taken along line **12-12** of the tubing bundle termination shown in **FIG. 11**.

[0026] **FIG. 13** is an oblique view of the tubing bundle termination shown in **FIGS. 11 and 12**.

[0027] **FIG. 14** is a longitudinal sectional view of a conical tubing anchor of the third embodiment of the tube bundle termination of the present invention.

[0028] **FIG. 15** is an oblique view of a typical helical tubing bundle consisting of seven equisized tubes.

[0029] **FIG. 16** is an oblique view of a fourth embodiment of the tubing bundle termination of the present invention.

[0030] **FIG. 17** is an oblique exploded view of the tubing bundle termination of **FIG. 16**.

[0031] **FIG. 18** is a plan view taken from the inlet/outlet side of the tubing bundle termination of **FIGS. 16 and 17**.

[0032] **FIG. 19** is a longitudinal sectional view taken along line **19-19** of **FIG. 18**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] The present invention provides an apparatus and method that permits an easily assembled anchorage for subsea tube bundles having high tensile capacity.

[0034] The tubing terminations are intended for use with tubing bundles composed of a multiplicity of steel tubes, wherein the individual tubes are maintained in constant relative angular positions and are arrayed in a bundle in a helical pattern without torsion. In such a tubing bundle, a center tube serves as a core and multiple other tubes are arrayed around the central tube by bending. The tubes need not all be the same size. Normally, the center tube is the largest of the tubes in the bundle. The tubes at an end of a section of a tubing bundle are terminated by means of the tubing terminations of the present invention. Connections are made by either mechanical means or by arc welding. However, in the drawings for the present invention, only welded connections between the bundle tubes and the terminations are shown.

[0035] The components of the main structural elements of the tubing termination embodiments of the present invention are typically made of carbon steel, high-strength/low-alloy steel, or stainless steel. A first embodiment **10** of the tubing termination is shown in FIGS. **1** to **5**.

[0036] Referring to **FIGS. 1 and 2**, the upper and lower sides of the tubing termination **10** are shown. As shown in the drawings, the upper side of the termination corresponds to the inlet or outlet side for the anchored tube bundle, while the lower side is where the tubes of the bundle are attached by welding. Strictly for providing a representative example, the tubing bundle in this case consists of ten equisized tubes, with a single center tube **91** and nine outer tubes **92**. A greater or lesser number of tubes could be utilized, and the sizes can differ for the individual tubes in a particular bundle.

[0037] **FIG. 15** shows a typical tubing bundle **90** with a straight core tube **91** and six helically spiraled tubes **92** closely arrayed around the core tube. For this tubing bundle **90** shown in **FIG. 15**, all seven tubes are of the same size.

[0038] The tubing termination **10** consists of a set of comating anchor blocks **11** and **20**, as well as a split clamp assembly **30** which holds the anchor blocks together. The center anchor block **11** supports the center tube **91** of the bundle is a right circular cylinder having a transverse upper flange **12** and a coaxial right circular through hole **13**. The outer cylindrical surface **14** of the center anchor block **11** is comateable with the outer anchor blocks **20** that serve to support the outer tubes **92** in the tube bundle **90**.

[0039] The inlet/outlet end **15** of the center tube **91** of the bundle **90** has a right circular cylindrical external upset having at its lower end a conical transition to the normal outer diameter of the center tube. The external upset diameter is a slip fit to the through hole of the center anchor block. Here, the bore of the inlet/outlet end **15** matches the bore of the center tube **91**. The inlet/outlet end **15** is welded to each of the upper and lower transverse ends of the anchor block **11** by circumferential fillet welds **17**. The inlet/outlet end **15** is attached to the center tube **91** by a circumferential butt or groove weld (not shown for clarity). Here, the other, upper side of the end **15** is identical to the lower side end and attachment by a circumferential butt or groove weld is made there to a tube of equal size to that of the center tube **91**. Alternatively, either or both of the connections could be made by commercially available compressive tube fittings.

[0040] Each outer anchor block **20** is an arcuate segment of an annular right circular cylindrical having an outwardly extending upper transverse flange **21**, a right circular partial cylindrical inner face, a symmetrically positioned right circular through hole **29** parallel to the axis of anchor block **20**, and a right circular partial cylindrical outer face **23**. The radius of the inner face **22** has the same radius as and is comateable with the outer cylindrical surface **14** of the center anchor block **11**. The upper transverse face of the outer anchor block **20** abuts the lower side of the upper flange **12** of the center anchor block **11** when the tubing termination is assembled. In the example shown here, all of the outer anchor blocks **20** are the same since the outer tubes **92** of the bundle **90** all have the same size.

[0041] A symmetrically positioned right circular through bolt hole **24** with its axis parallel to the longitudinal axis of the outer anchor block **20** and extending through upper flange **21** mounts downwardly extending hex-head retainer screw **25**. The planar lateral sides **28** of outer anchor block **20** can be coplanar with the axis of rotation of the block. Alternatively, as shown herein, the individual outer anchor blocks **20** can be made by cutting a solid annular ring with radial saw cuts which have a finite kerf width. The number of outer anchor blocks **20** corresponds to the number of outer tubes **92** in the tubing bundle **90**.

[0042] The inlet/outlet end **27** for the attached outer bundle tube **92** supported by outer anchor block **20** is structurally identical to the inlet/outlet end **15** for the center tube **91**. Circumferential butt or groove welds again make the connections of the inlet/outlet end **27** to the tube **92** and the tube on the opposed end. The inlet/outlet end **27** has a close slip fit to the through hole **29** and is attached to the upper and lower transverse faces of the anchor block by circumferential fillet welds **26**. Again, either or both of the connections alternatively could be made by commercially available compressive tube fittings.

[0043] The split clamp assembly **30** consists of first clamp half **31**, second clamp half **40**, and the clamp studs **50** with clamp nuts **51** required to draw the clamp halves together.

Sufficient space is provided between the clamp halves **31** and **40** so that they do not abut prior to fully clamping together the assembled anchor blocks **11** and **20**. The split clamp assembly **30** surrounds and retains the center anchor block **11** and its surrounding set of outer anchor blocks **20**.

[**0044**] The first clamp half **31** and the second clamp half **40** are identical except for their respective patterns of drilled and tapped retainer screw holes **34**. The arrangements of retainer screw holes are unequal for the clamp halves in this case because there are an odd number of outer anchor blocks **20**. In cases where the number of outer anchor blocks is even, then the hole patterns of both clamp halves and hence the clamp halves **31** and **40** themselves are identical.

[**0045**] Each clamp half **31** and **40** has a right circular nearly semicylindrical annular body with the diameters greater than the axial length, an externally extending transverse upper reinforcing flange **33** and **43** respectively, and an externally extending transverse lower reinforcing flange **35**. Drilled and tapped with their hole axes parallel to the axis of the clamp and into the upper transverse faces of the clamp halves **31** and **40** are multiple retainer screw holes **34**. The number of retainer screw holes **34** is equal to the number of outer anchor blocks **20**. The inner nearly semicylindrical faces **36** of the clamp halves **31** and **40** are close fits to the outer partial cylindrical faces **23** of the outer clamp blocks **20**. The upper transverse faces of the clamp halves abut the lower transverse faces of the upper flanges **21** of the outer anchor blocks **20**, while the retainer screws **25** are threadedly engaged with the retainer screw holes to mount the outer clamp blocks **20** to the clamp halves.

[**0046**] Extending outwardly parallel to and slightly offset from the diametrical plane perpendicular to the vertical plane of symmetry for each clamp half **31** and **40** are thick rectangular clamping ears **37**. On each clamping ear, two through clamping bolt holes **38** are drilled horizontally perpendicular to the inner face of the clamping ears **37** symmetrically about the horizontal midplane of the clamp halves. When the clamp halves **31** and **40** are assembled around the anchor blocks **11** and **20**, the clamp studs **50** are extended through the clamping bolt holes **38** and then clamp nuts **51** are used to draw the clamp halves together so that the tubing termination **10** is rigidized.

[**0047**] **FIGS. 6 and 7** show how the tubing termination **10** can be attached to a bend limiting assembly **60** so that the tube bundle **90** will not be overstressed by minor rotations at its anchorage **10**. The bend limiter assembly **60** is a simple ball and socket arrangement with an integral abuttable flange travel stop **84** that serves to limit the amount of rotation of the assembly. The tubing termination **10** can be mounted on the ball or swivel head **80** portion of the bend limiting assembly **60**. The bend limiter assembly **60** consists of a lower socket **61**, two identical retainer halves **70**, and the swivel head **80**.

[**0048**] The lower socket **61** is a thick right circular cylindrical annular disk with an outwardly protruding transverse flange **63** and an interior cavity, both on its upper side. Flange **63** has a regular bolt hole circle pattern of transverse through holes in its periphery. The interiorcavity on its lower side has a coaxial spherically shaped cup **62** bore, wherein the center of the spherical cup is located at the transverse upper shoulder **65** of the lower socket **61**. An annular open-sided groove detent recess **64** having a vertical outer side and a transverse bottom shoulder is located at the interior edge of the upper shoulder **65**.

[**0049**] Two identical retainer halves **70** are formed by separating a modified lower socket assembly **61** into two segments with a diametrical cut. These retainer halves are mounted in mirror image positions inverted relative to the lower socket **61** and are retained by studs **87** and hex nuts **88** through the bolt holes in the flange **76** and the comating bolt holes in the flange **63** of the lower socket. However, instead of having a detent recess **64** on its lower shoulder **77** that is equivalent to the upper shoulder **65** of the lower socket **61**, the retainer halves have a male boss **71** which is comateable with the detent recess **64**. Thus, the retainer halves **70** each have a spherical cup **72**, a flange **76**, and a lower shoulder **77**. When mounted together, the retainer halves **70** and the lower socket **61** form a partial spherical pocket that serves as a support for the spherical ball joint mounted in their interior.

[**0050**] Swivel head **80** is of annular construction and consists of, from its upper end, the following coaxial elements: a transverse right circular annular flange **81**, a thin wall circular tubular neck **83**, and a lower spherical surface **82** with a transverse flange travel stop **84** through its spherical center. The outer diameter of the flange travel stop **84** is sufficiently less than the interior recess of the lower socket **61** and the retainer halves **70** that the swivel head **80** can rotate without contacting the cylindrical interior walls of those parts. The diameter of the spherical surface **82** is comateable with and pivotable within the spherical recess formed by the spherical cups **62** and **72** of the lower socket **61** and the retainer halves **70**, respectively. The upper end of swivel head **80** has a circular through bore **85** extending downwardly from the flange **81** to the center of the spherical surface. Below the center of the spherical surface **82**, the through bore **85** is outwardly flared. The amount of rotation which the swivel head can make about any horizontal axis through the spherical center of the socket formed by the spherical cups **62** and **72** is limited by the engagement of the travel stop **84** with the interior transverse faces of the lower socket **61** and the retainer halves.

[**0051**] On the upper transverse face of the flange **81** are mounted two mirror image upwardly projecting mounting projections **86**. These mounting projections have vertical coplanar mounting faces that are offset from the vertical axis of the swivel head **80**. The amount of offset of these mounting faces is equal to the amount of offset of the back side of the clamping ears **37** of the split clamp assembly **30**. Drilled and tapped horizontal axis holes are provided in the mounting projection coplanar faces so that the clamp studs **50** of the split clamp assembly can be engaged therein and the tubing termination **10** thereby mounted to the mounting projections.

[**0052**] **FIGS. 8, 9**, and **10** show a second embodiment **100** of the tube bundle termination of the present invention. This second embodiment uses a conical socket in its clamp ring **130** to engage frustroconical surfaces in its outer anchor blocks **120**, while the center anchor block **111** is retained by the engagement of its exterior frustroconical surfaces with comating surfaces on the interior side of the outer anchor blocks. As seen best in **FIGS. 9 and 10**, the center anchor block **111** is a cylinder with transverse end surfaces, an axial through bore **113**, and an outer frustroconical surface **114** having a low taper angle. The center bundle tube **91** is welded with a butt or groove weld to the inlet/outlet end **15** for the tube. The inlet/outlet end **15** has a slip fit within the through bore **113** and is retained therein by means of upper and lower circumferential fillet welds **17** at the penetration of the inlet/outlet end through the transverse faces of the anchor block **111**.

[**0053**] The outer anchor blocks **120** are angular segments cut from an annular ring having transverse ends and coaxial inner and outer frustroconical surfaces which taper in the same direction. The inner frustroconical surface has the same taper angle as the outer frustroconical surface **114** of the center anchor block **111**, and these two surfaces are comateable over a substantial portion of their axial length. Thus, each outer anchor block **120** has an inner partial frustroconical surface **122**, an outer partial frustroconical surface **123**, and two planar lateral sides **128** formed by diametrical cuts of the annular ring described above. A through bore **129** extends through the outer anchor block **120** parallel to the frustroconical axis and on the vertical plane of symmetry of the anchor block. An outer bundle tube **92** is welded with a butt or groove weld to the inlet/outlet end **27** for the tube. The inlet/outlet end **27** has a slip fit within the through bore **129** and is retained therein by means of upper and lower circumferential fillet welds **26** at the penetration of the inlet/outlet end through the transverse faces of the anchor block **111**.

[**0054**] The clamp ring **130** for tubing termination **100** is an annular right circular cylindrical ring having a coaxial inner frustroconical bore **136** which is comateable with the outer partial frustroconical surfaces **123** of the outer anchor blocks **120**. The assembly of the tubing termination **100** thus has the interior bore **136** of the clamp ring **130** filled with one outer anchor block **120** for each outer tube **92** in the tubing bundle **90** to form a complete assemblage of outer anchor blocks to fill the conical cup of the clamp ring. A center anchor block **111** is then positioned in the center frustroconical socket formed by the inner partial frustroconical surfaces **122** of the outer anchor blocks **120**. The taper angles of the frustroconical surfaces of the assemble can be selected to make the tapers either self-releasing or alternatively to have the angle of the comating frustroconical surfaces sufficiently small that the assembled anchor blocks are retained by friction against unintentional release.

[**0055**] A third embodiment **200** of the tubing termination is similar to the first embodiment **10**, but the inlet/outlet ends **215** and **227** provided for the tubes **91** and **92** in the tube bundle **90** have frustroconical exterior surfaces which are socketed in comating frustroconical bores in the anchor blocks **211** and **220**. **FIGS. 11 through 14** show the details of tube bundle termination **200**.

[**0056**] As shown in the drawings, the upper side of the termination **200** corresponds to the inlet or outlet side for the anchored tube bundle **90**, while the lower side is where the tubes of the bundle are attached by welding. Strictly for providing a representative example, the tubing bundle in this case consists of seven equisized tubes, with a single center tube **91** and six outer tubes **92**.

[**0057**] The third embodiment tubing termination **200** consists of a set of comating anchor blocks **211** and **220**, as well as a split clamp assembly **30** which holds the anchor blocks together. The center anchor block **211** that supports the center tube **91** of the bundle is a right circular cylinder having a transverse upper flange **212** and a coaxial frustroconical through hole **213**. The diameter of hole **213** is reduced from top to the bottom end. The outer cylindrical surface **214** of the center anchor block **211** is comateable with the outer anchor blocks **220** that serve to support the outer tubes **92** in the tube bundle **90**. The inlet/outlet end **215** of the center tube **91** of the bundle **90** has a frustroconical external upset with a low angle and a downwardly reducing diameter. The inlet/outlet end **215** has at its lower end a conical transition to the normal outer diameter of the center tube **91**. The external upset frustroconical surface is comateable with the through hole **213** of the center anchor block. Here, the bore of the inlet/outlet end **215** matches the bore of the center tube **91**. The inlet/outlet end **215** is not welded to the anchor block **211**, but is instead retained by frictional engagement. The inlet/outlet end **215** is attached to the center tube **91** by a circumferential butt or groove weld (not shown for clarity). Here, the other, upper side of the end **215** is identical to the lower side end and attachment by a circumferential butt or groove weld is made there to a tube of equal size to that of the center tube **91**. Alternatively, either or both of the connections could be made by commercially available compressive tube fittings.

[**0058**] Each outer anchor block **220** is an arcuate segment of an annular right circular cylindrical having an outwardly extending upper transverse flange **221**, a right circular partial cylindrical inner face **222**, a symmetrically positioned frustroconical through hole **229** parallel to the axis of anchor block **220**, and a right circular partial cylindrical outer face **223**. The radius of the inner face **222** is comateable with the outer cylindrical surface **214** of the center anchor block **211**. The upper transverse face of the outer anchor block **220** abuts the lower side of the upper flange **212** of the center anchor block **211** when the tubing termination is assembled. As shown here, all of the outer anchor blocks **220** are the same since the outer tubes **92** of the bundle **90** all have the same size. A symmetrically positioned right circular through bolt hole **224** with its axis parallel to the longitudinal axis of the outer anchor block **220** and extending through upper flange **221** mounts downwardly extending hex-head retainer screw **225**. The planar lateral sides **228** of outer anchor block **220** can be coplanar with the axis of rotation of the block. Alternatively, as shown herein, the individual outer anchor blocks **220** can be made by cutting a solid annular ring with radial saw cuts which have a finite kerf width. The number of outer anchor blocks **220** corresponds to the number of outer tubes **92** in the tubing bundle **90**.

[**0059**] The inlet/outlet end **227** for the attached outer bundle tube **92** supported by outer anchor block **220** is structurally identical to the inlet/outlet end **215** for the center tube **91**. The connections of the inlet/outlet end **227** to the tube **92** and the tube on the opposed end are again made by circumferential butt or groove welds. The inlet/outlet end **227** is firmly comateable with the through hole **229**. Again, either or both of the connections alternatively could be made by commercially available compressive tube fittings.

[**0060**] A fourth embodiment tubing termination **300**, shown in **FIGS. 17-19**, is in most respects very similar to the first embodiment **10**. The difference resides in the approaches to retaining the tube bundle and its attached inner and outer anchor blocks in the split clamp assembly whenever there is an outward thrust on the bundle. In the case of tubing termination **300**, the anchor blocks **311** and **320** are both restrained in axial motion in either direction by flanges on both ends of the anchor blocks.

[**0061**] Tubing termination **300** consists of a set of comating anchor blocks **311** and **320**, as well as a split clamp assembly **30** that holds the anchor blocks together. The split clamp assembly is the same in all details as is used for the first embodiment **100**. The center anchor block **311** that supports the center tube **91** of the bundle is a right circular cylinder having a transverse upper flange **312**, a coaxial right circular through hole **313**, and a transverse lower flange **318** that is a mirror image of the upper flange **312**.

[**0062**] The outer cylindrical surface **314** of the center anchor block **311** is comateable with the outer anchor blocks **320** that serve to support the outer tubes **92** in the tube bundle **90**. The inlet/outlet end **15** of the center tube **91** of the bundle **90** has a right circular cylindrical external upset having at its lower end a conical transition to the normal outer diameter of the center tube. The external upset diameter is a slip fit to the through hole of the center anchor block. Here, the bore of the inlet/outlet end **15** matches the bore of the center tube **91**. The inlet/outlet end **15** is welded to each of the upper and lower transverse ends of the anchor block **311** by circumferential fillet welds **17**. The inlet/outlet end **15** is attached to the center tube **91** by a circumferential butt or groove weld (not shown for clarity). Here, the other, upper side of the end **15** is identical to the lower side end and attachment by a circumferential butt or groove weld is made there to a tube of equal size to that of the center tube **91**. Alternatively, either or both of the connections could be made by commercially available compressive tube fittings.

[**0063**] Each outer anchor block **320** is an arcuate segment of an annular right circular cylindrical having an outwardly extending upper transverse flange **321**, a right circular partial cylindrical inner face **322**, a symmetrically positioned right circular through hole **229** parallel to the axis of anchor block **320**, a right circular partial cylindrical outer face **323**, and an outwardly extending transverse lower flange **330**. The radius of the inner face **322** has the same radius as and is comateable with the outer cylindrical surface **314** of the center anchor block **311**. The upper transverse face of the outer anchor block **320** abuts the lower side of the upper flange **312** of the center anchor block **311** when the tubing termination is assembled. Likewise, the lower transverse face of the outer anchor block **320** abuts the upper side of the lower flange **318** of the center anchor block **311** when the tubing termination **300** is assembled.

[**0064**] As shown here, all of the outer anchor blocks **320** are the same since the outer tubes **92** of the bundle **90** all have the same size. The planar lateral sides **328** of outer anchor block **320** can be coplanar with the axis of rotation of the block. Alternatively, as shown herein, the individual outer anchor blocks **320** can be made by cutting a solid annular ring with radial saw cuts which have a finite kerf width. The number of outer anchor blocks **320** corresponds to the number of outer tubes **92** in the tubing bundle **90**.

[**0065**] The inlet/outlet end **27** for the attached outer bundle tube **92** supported by outer anchor block **320** is structurally identical to the inlet/outlet end **15** for the center tube **91**. The connections of the inlet/outlet end **27** to the tube **92** and the tube on the opposed end are again made by circumferential butt or groove welds. The inlet/outlet end **27** has a close slip fit to the through hole **329** and is attached to the upper and lower transverse faces of the anchor block by circumferential fillet welds **26**. Again, either or both of the connections alternatively could be made by commercially available compressive tube fittings.

OPERATION OF THE INVENTION

[**0066**] The operation of the tube bundle terminations of the present invention is concerned with the assembly of the structures, since the apparatus is stationary and passive following assembly. The characteristic of the tube bundle construction which facilitates the use of the type of structural arrangement used in the present invention is the lack of torsion induced in the individual tubes when the bundle is fabricated. The outer tubes in the bundle are laid into their helical pattern utilizing only bending, rather than torsion, while the center tube is neither bent nor twisted. This causes the maintenance of alignment between the tube ends of the bundle and the elements of the tube bundle termination to be much easier when the anchor blocks of the termination are separated to attach the tubes. Generally, following the attachment of the tube bundle terminations to the tubes, only elastic bending of the separated outer tubes is required to reestablish the desired compact bundle geometry at the end of the bundle.

[**0067**] The assembly of the tube bundle termination **100** proceeds as follows. The ends of the outer tubes of the bundle at the end of the bundle are separated sufficiently so that there is sufficient room for a welder to operate around any one of the tubes in the bundle. At this point, a circumferential butt or groove weld is made to align and join each of the outer tubes **92** and the inner tube **91** to an outer tube inlet/outlet end **27** or an inner tube inlet/outlet end **15**, respectively. Following this, the inner tube inlet/outlet end **15** and each of the outer tube inlet/outlet ends **27** is slipped into the through bore **13** of center anchor block **1** or the through bore **29** of outer anchor block **20**, as appropriate.

[**0068**] At this point, the anchor blocks **11** and **20** are reassembled by elastically bending the tubes **92** into their packed pattern as shown in **FIGS. 1, 2**, and **4**. Following this, the split clamp assembly **30** is assembled around the assembled anchor block pattern by engaging the clamp halves **31** and **40** around the anchor blocks and then tightening the nuts **51** on the studs **50** after insertion of the studs through the clamping bolt holes **38**. At this point, match marks between each tube inlet/outlet end **15** or **27** and its corresponding anchor block can be made. Alternatively, tack welds of the tube inlet/outlet ends **15** or **27** with their respective anchor blocks **11** or **20** can be made to hold the desired alignment therebetween. At this point, the clamp assembly **30** can be removed, the anchor blocks reseparated, and the circumferential fillet welds **17** made to rigidly affix the inlet/outlet ends **15** or **27** to their respective blocks. If tack welds were not used to hold alignment, then following anchor block separation, the blocks are aligned with their respective tubes using the marks prior to the making of the final welds **17**.

[**0069**] When the connecting welds **17** are completed, the anchor blocks **11** and **20** can be reclustered and the assembly completed by clamping the assembly **10** together using the split clamp assembly **30**. At this time, the bolt holes **24** of the outer anchor blocks **20** are aligned with their respective retainer screw holes **34** and **44** in the first clamp half **31** and second clamp half **40**, respectively. Engagement of the retainer screws **25** through the bolt holes **24** and into the retainer screw holes **34** and **44** completes the assembly of the clamp. After this assembly operation, the tube bundle termination **10** is fully rigidized and can resist axial loads in the direction of the tube bundle **90** by abutment of the upper flange **12** of the center anchor block **11** on the upper surface of the outer anchor blocks **20** and the abutment of the upper flange **21** of the outer anchor blocks **20** on the upper surface of the split clamp assembly **30**. The retainer screws **25** and friction between the center anchor block **11** and its surrounding outer anchor blocks **20** provide resistance to axial loads in the other direction.

[**0070**] If the tubing termination **10** is to be used with the bend limiter assembly **60** shown in **FIGS. 6 and 7**, the split clamp assembly **30** is first removed and the anchor blocks **11** and **20** and tubes **91** and **92** passed through the through bore **85** of the swivel head **80**, assuming that sufficient clearance is available. If the clearance is insufficient, then the bend limiter assembly **60** must be slid over the ends of the tubing bundle prior to welding the inlet/outlet tube ends **15** and **27** to their respective anchor blocks **11** or **20**. After the tubing termination **100** is extended beyond the upper surface **81** of the swivel head **80** of the bend limiter assembly **60**, the flange nuts **51** on one side of the split clamp assembly **30** are removed so that the studs **50** can be engaged into the drilled and tapped holes mounting projections **86** of the swivel head **80** of the bend limiter assembly **60**.

[**0071**] The assembly of the second embodiment **100** of the tube bundle termination proceeds in a similar manner to that for the first embodiment **10**. For the termination **100**, the clamp ring **130** must be slipped over the end of the tube bundle **90** prior to the final assembly welds **17** being used to join the anchor blocks **111** and **120** to their respective inlet/outlet tube ends **15** and **27**. The assembly of the clamp **130** onto the clustered anchor blocks **111** and **120** is performed by sliding the clamp **130** over the clustered anchor blocks until the inner frustroconical face **136** of the clamp is tightened onto the outer frustroconical surfaces **123** of the outer anchor blocks **120**. At this point, abutment of the frustroconical faces of the anchor blocks **111** and **120** and clamp **130** resists axial loads in the tube bundle direction. Loads in the opposite direction are resisted by friction between the frustroconical faces.

[**0072**] The assembly of the third embodiment **200** of the tube bundle termination also proceeds similarly to that of the first embodiment **10** with the following exceptions. The third embodiment **200** utilizes frustroconical surfaces between the inlet/outlet tube ends **215** and **227** and their respective anchor blocks **211** and **220** to socket and thereby anchor the inlet/outlet end in the termination **200**. Accordingly, the anchor blocks **211** and **220** must be slipped over the ends of the tubes **91** and **92** of the tube bundle **90** prior to welding of the inlet/outlet tube ends **215** and **227** to their respective tubes by butt or groove circumferential welds. Rotational alignment of the inlet/outlet tube ends is readily achieved without advance fitup or marking, since the inlet/outlet ends **215** and **227** can freely rotate in their respective frustroconical through bores **213** and **229** until pulling them firmly into abutment tightens them. The assembly of the split clamp **30** and the retention in the clamp of the anchor blocks **211** and **220** is identical to that of termination **10**.

[**0073**] The fourth embodiment of the tube bundle termination **300** is very similar to that of termination **10**. The difference between the two embodiments is related to the means for resisting axial loads produced by thrust on the end of the tube bundle **90**. The tube bundle termination **300** is assembled in a manner identical to that used for the termination **10**. For this embodiment **300** when axial tension is induced in the tube bundle **90**, the upper flange **312** of the center anchor block **311** abuts the upper transverse faces of the outer anchor blocks **320**, while the upper flanges **321** of the anchor blocks **320** abut the upper side of the split clamp assembly **30**. For thrust loads from the tube bundle **90**, the lower flange **318** of the center anchor block **311** abuts the lower transverse faces of the outer anchor blocks **320**, while the lower flanges **330** of the anchor blocks **320** abut the lower side of the split clamp assembly **30**. Note that the retainer screw holes **34** and **44** of the first and second clamp halves **31** and **40**, respectively, can be omitted for this embodiment.

ADVANTAGES OF THE INVENTION

[**0074**] The advantages of the present invention directly result from the ability to physically separate the anchor blocks of the tube bundle terminations by sufficient space that the necessary connecting welds between the tubes **91** and **92** of the tube bundle **90** and their respective inlet/outlet tube ends can be readily made. This ability directly results from the segmentation of the anchor assembly into a set of anchor blocks wherein one block is provided for each tube in the tube bundle. Likewise, if the inlet/outlet tube ends are directly welded to their respective inner and outer anchor blocks, as is the case for tube bundle terminations **10**, **100**, and **300**, the anchor blocks can be sufficiently separated to permit easily making those welds.

[**0075**] Because of this ability to separate the anchor blocks, the center-to-center spacing of the tubes in the termination can be decreased significantly, since welding does not have to be done in the inter-tube spaces of the assembled terminations of the present invention. Consequent to the compactness of the present invention, its weight and cost for construction as well as the assembly cost are significantly reduced.

[**0076**] The present invention provided a more flexible means for terminating tube bundles than conventional welding or potting the tubes into a socket with a plastic. Should there be a problem with one tube, the termination assembly readily can be disassembled, repaired, and reassembled. This flexibility greatly improves the maintainability of the termination.

[**0077**] The termination **200** can be assembled with particular ease, so that it offers the quickest assembly of the set of terminations of the present invention. For cases of very low thrust loads applied to the termination by the tube bundle, the second embodiment **100** or the third embodiment **200** are satisfactory. The first 10 and, particularly, the fourth embodiment **300** of the present invention offer very high resistance to thrust loads.

[**0078**] As readily may be understood by those skilled in the art, the present invention may be varied in its details without departing from the spirit of the invention. For example, the configuration of the inlet/outlet tube ends may be varied. Likewise, compression tube fittings may be utilized as an alternative to welded connections between the tubes of the tube bundle and the terminations of the present invention.

What is claimed is:

1. A subsea termination device for a helical tubing bundle comprising:

a) a center anchor block attached to a center tube of a tubing bundle;

b) a plurality of outer anchor blocks, each outer anchor block attached to an outer tube of the tubing bundle, wherein an interior surface of each outer anchor block is comateable with an outer surface of the center anchor block to form an anchor block assemblage; and

c) a ring clamp engageable around the anchor block assemblage to thereby rigidize the anchor block assemblage.

2. The subsea termination device of claim 1, wherein the center anchor block is attached to the center tube by welding.

3. The subsea termination device of claim 1, wherein the outer anchor blocks are attached to the outer tubes by welding.

4. The subsea termination device of claim 1, wherein the ring clamp is a split clamp assembly having a first clamp half and a second clamp half cojoined by threaded fasteners.

5. The subsea termination device of claim 4, wherein a flange on each outer anchor block is mounted on the first or second clamp half.

6. The subsea termination device of claim 1, wherein each outer anchor block comprises: a transverse flange, a right circular partial cylindrical inner face, a symmetrically positioned right circular through hole, and a right circular partial cylindrical outer face.

7. The subsea termination device of claim 1, wherein each outer anchor block is retained within two opposed transverse flanges of the center anchor block.

8. The subsea termination device of claim 5, wherein the radius of the inner face of the outer anchor block has a substantially similar radius as an outer cylindrical surface of the center anchor block.

9. The subsea termination device of claim 1, wherein an upper transverse face of the outer anchor block abuts a flange of the center anchor block.

10. The subsea termination device of claim 1, further comprising a bend limiting assembly.

11. The subsea termination device of claim 10, wherein the bend limiting assembly includes a lower socket, two mirror-image retainer halves, and a swivel head.

12. The subsea termination device of claim 1, wherein the center anchor block and the outer anchor blocks have comating frustoconical surfaces.

13. The subsea termination device of claim 1, wherein the outer anchor blocks constitute a segmented ring.

14. The subsea termination device of claim 1, wherein the center anchor block and the outer anchor blocks have a radially outwardly extending transverse flange, wherein the flange of the center anchor block abuts a side of each of the outer anchor blocks and the flange of the outer anchor blocks engages the ring clamp.

15. A termination device comprising:

a) a center anchor block having an outer surface of rotation, wherein the center anchor block is attached to a center tube of a tubing bundle;

b) a plurality of outer anchor blocks, each outer anchor block attached to an outer tube of the tubing bundle, wherein an interior surface of each outer anchor block is comateable with an outer surface of the center anchor block to form an anchor block assemblage;

c) a ring clamp engageable around the anchor block assemblage to thereby rigidize the anchor block assemblage; and

d) a retaining means for restraining the axial motion of the center and outer anchor blocks.

16. The termination device of claim 15, wherein the retaining means includes a pair of opposed flanges on the inner and the outer anchor blocks.

17. The termination device of claim 15, wherein the retaining means includes:

a) a pair of opposed center anchor block flanges, one flange extending radially outward from a first end of the center anchor block and a second flange extending radially outward from a second end of the center anchor block;

b) a pair of opposed outer anchor block flanges, one flange extending radially outward from a first end of each outer anchor block and a second flange extending radially outward from a second end of each outer anchor block;

c) the flange at the first end of the center anchor block abuts the first end of each of the outer anchor blocks;

d) the flanges at the first end of the outer anchor blocks abut a first side of the ring clamp;

e) the flange at the second end of the center anchor block abuts the second end of each of the outer anchor blocks; and

f) the flanges at the second end of the outer anchor blocks abut a second side of the ring clamp;

whereby the termination device permits the anchor block assemblage to resist axial motion in either direction.

18. The termination device of claim 15, wherein the outer anchor blocks constitute a segmented ring.

19. The termination device of claim 15, wherein

a) the outer surface of rotation of the center anchor block is frustroconical with a taper in a first direction;

b) the interior surface of each outer anchor block is frustroconical with a taper in the same direction as the frustroconical outer surface of the center anchor block and comateable with the outer surface of the center anchor block;

c) an exterior surface of each outer anchor block is frustroconical with a taper in the same direction as the frustroconical outer surface of the center anchor block; and

d) an inner face of the ring clamp is frustroconical with a taper in the same direction as the frustroconical outer surface of the center anchor block and comateable with the exterior surface of the outer anchor blocks, thereby permitting the anchor block assemblage to resist axial movement in the said taper direction.

20. The termination device of claim 15, further comprising a bend limiting assembly.

21. The termination device of claim 20, wherein the bend limiting assembly consists of:

a) a socket element having a frustrospherical internal cavity;

b) a ball element having:

i) a cylindrical neck supporting a coaxial frustrospherical external upset comateable with the internal cavity of said socket element;

ii) a coaxial through bore; and

iii) a transverse mounting surface with anchorages for the attachment of the ring clamp, whereby the ball element is rotatable in the socket element within limits imposed by the impingement of the cylindrical neck against the socket element.

* * * * *